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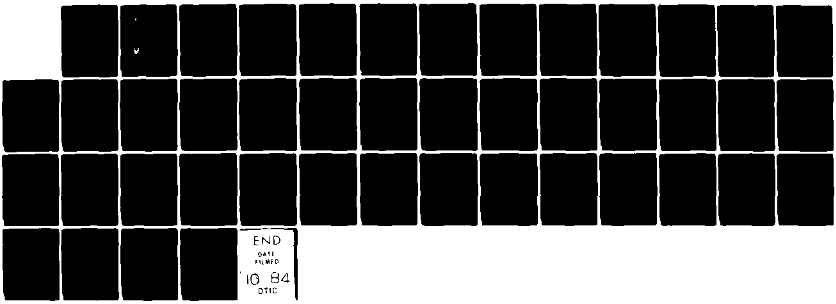

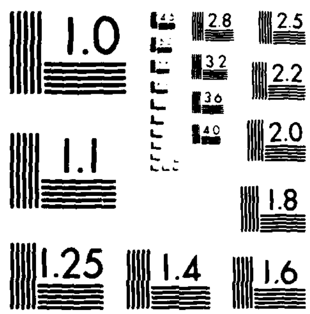

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TECHNICAL REPORT RD-83-14

(12)

AERODYNAMIC INVESTIGATION OF THE INFLUENCES ON A SUBMISSILE FLIGHT CHARACTERISTIC OF (1) BODY VENTILATION AND (2) A PANEL FLYING IN ITS VICINITY

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JULY 1983

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898

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Two Body Aerodynamic Effects
Submissile Dispensing
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In an attempt to explain observed submissile flight anomalies occurring during the Flight Demonstration Program of Assault Breaker Development, an aerodynamic investigation was conducted. Two wind tunnel tests were made: one investigated effects of submissile body openings with possible air flowthrough, and the other a submissile and a cover panel in close proximity - as might occur during ejection. Selected data from these tests are presented herein to illustrate these influences on the submissile's flight responses in the ejection plane.

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Test results revealed decreases in total normal force and fin lift with corresponding stability changes due to the existence of body slots, and the cover panel's presence produced flowfield changes that were equivalent to submissile attitude changes of approximately four degrees. (Ou...

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A1

LIST OF ILLUSTRATIONS

I. INTRODUCTION

In flight tests conducted during the ASSAULT BREAKER Technology Demonstration Program, terminally guided submissiles (TGSM's) were dispensed from the PATRIOT derivative (T-16) carrier missile. On several occasions, unsatisfactory submissile flight behavior was noted during the post-dispense period. These anomalies included tumbling flight, large uncommanded maneuvers and apparent contact or collision with compartment cover panels. These cover panels were removed from the missile by the force imparted during stores ejected from their storage compartments. Design expectations were that the lightweight, relatively flat panels, would be instantaneously removed from the region by aerodynamic forces. The scarcity of flight telemetry data on the affected submissiles and the low resolution flight photographic coverage did not provide sufficient explanation of the flight responses. A study of the existing aerodynamic data as a possible diagnostic source revealed that less than adequate configuration modeling was used to obtain the available experimental data. No existing source of information could be found to predict the influence of the cover. Therefore, wind tunnel investigations were accomplished to determine the influences on the TGSM during flight.

Two tunnel entries were made during this investigation. One test involved a full scale model of the TGSM. In this model, particular attention was given to insure the body slots and fin root chord regions match the flight hardware. Also, body porosity to give internal flowthrough possibility was incorporated in this model. These body details had been omitted in the original tests of the TGSM. Several runs were conducted on this model with simulated compartment cover panels rigidly affixed to provide insight into such a configuration.

The other wind tunnel test utilized a captive trajectory system to investigate the cover panel's influence by testing a 1/4 scale version of the two bodies at preselected relative positions representative of dispense positions and attitudes. For this test no attempt to include TGSM body small geometry details were made. Testing was conducted during October 1982, in the Vought High Speed Tunnel.

This report presents only portions of the tests results to provide insight into the influences discussed above on longitudinal static stability and fin performance. Lateral plane information, axial force and many other test conditions, model orientations, attitudes and relative body positions are presented in part as plotted data and totally as tabulated data in References 1 and 2. Test techniques, rationale, procedures and difficulties, as well as detailed model drawings, are presented in Reference 3. All data obtained during the tests has been entered in a computer data base at the US Army Missile Command and documentation describing content and user instructions may be found in Reference 4.

A. Test Apparatus

Test Facility - The Vought High Speed Wind Tunnel is an atmospheric exhaust, blowdown tunnel with a 4 ft x 4 ft cross section test section. This tunnel can be operated in the subsonic, transonic, supersonic regime by test

sections changes and control of diffuser operation. A complete description of this facility may be found in Reference 5.

The tunnel was operated over the mach numbers range of 0.66 to 1.30 during testing of the full scale TGSM (Series A). Data was recorded for most test runs as the model was varied at a preselected rate in angle of attack by a computerized control system and data was recorded at a selected sampling rate.

The TGSM/Panel interference test was conducted only at a representative dispense mach number ($M \simeq 1.0$). During testing the captive trajectory system was employed to position the two bodies at pre-selected positions through the area of interest in the ejection plane. Only longitudinal and vertical separation effects were investigated for various changes in the bodies' attitudes in that plane.

B. *Test Articles*

Details of the primary test article tested during the full scale (Series A) investigation are presented in Figure 1. The body openings detailed on this drawing include the forward fin slot (for storage of the forward folding fin), the fin root chord-body junction area (for clearance of fin actuator mechanism), and the rear slots (utilized during submissile assembly process).

To obtain data to evaluate slot effects, a configuration with an identical external envelope but with no body opening was tested. This configuration is designated (B2). Fin loads data were obtained from configuration B5 which had closed body slots but by necessity clearance holes were allowed in the vicinity of the fin root region.

Other configurations tested in this full scale model series but not covered in this report, were a cover panel in contact with the model and body alone versions of the two body variations.

The Series B (1/4 scale) test hardware is shown in Figure 2. The test measured forces on the TGSM with the cover panel in the vicinity. No forces were measured on the panel, and the captive trajectory systems were used to move the two bodies into relative positions to allow an investigation of a selected grid pattern in the plane containing the two bodies. One other configuration investigated in this test was the TGSM with the fins nearest the panel removed. This was intended to simulate conditions that might occur if a panel/TGSM collision prevented deployment of these fins. No data from that configuration is presented here (See Reference 2).

Instrumentation included in the test articles was a six component internal strain gage balance, a five component fin balance on each of the four fins, and base pressure measurements on the full scale TGSM (Series A). The 1/4 scale TGSM model (Series B) contained an internal six component balance and base pressure measurements provisions.

II. PRESENTATION OF DATA

As previously stated, the aim of this report is to present illustrative data to provide insight into the primary reasons for testing, i.e., body slots and panel presence effects on the TGSM. To accomplish this, only a small portion of the total data was selected. To totally demonstrate body slot effects under all conditions tested, i.e., various mach numbers, fin deflections, roll positions, angles of attack and configuration changes, 875 pages of tabulated data, which were obtained in the Series A test, are presented in Reference 1. One hundred sixty-three pages of tabulated data are used to present the data obtained during the Series B test (1/4 scale TGSM/panel) are presented in Reference 2.

Estimations of inaccuracies included in these data are presented in the references cited above. Generally, these values constitute no significant portion of the reported values and are noteworthy only in fin balance data obtained at inconsequential load levels.

Run schedules for each test series are presented in Tables 1 and 2. The runs from which selected data are presented herein are denoted.

The data presented in Figures 3 and 4 show total body normal force and pitching moment coefficients for the body with and body without slots. These figures reveal a small decrease in total normal due to the body slot effects. The onset of the normal force changes can generally be seen to occur between 5 and 10 degrees angle of attack and can be characterized as a loss approaching 10 percent of normal force throughout the range to $\alpha \approx 20^{\circ}$. Above this attitude normal stronger influence of the nose's contribution to the aerodynamics lessen the bodies contribution to total force developed on both configurations. The pitching moment data (Figure 4) shows the body slot effects to be a decrease in stability. This decrease is most pronounced at the transonic/supersonic Mach numbers, and generally persist throughout the angle of attack range in the supersonic range.

Data showing fin performance on the slotted and unslotted versions of the TGSM is presented in Figures 5 and 6. Only limited sealed slot fin data was obtained that was not influenced by mechanical interference on the fin balance by the installed air seals. Only those fin data obtained from configuration B5T1 (see Table 1) are considered sufficiently free from this "grounding" to be useful. Presented in the fin data are fin normal forces and hinge moments about the existing hinge line. Data is presented at a representative dispense Mach number ($M = 0.95$) for a fin located on the windward side (fin 2) of the TGSM and a fin located on the leeward side (fin 1).

The amount of fin lift losses resulting from the body slots presence is illustrated in Figure 5a and 5c for a windward fin and in Figure 6a and 6c for a leeward fin. The lift loss is apparent above pitch angle of 5 to 7 degrees greater than the attitude where fin incidence angle equals 0 degrees. This loss is shown at maximum lift attitude to yield fin loads only 75 to 80 percent of fin loads unaffected by body ventilation. This decrease in fin normal force is shown in Figure 5b and 5d and 6b and 6d to produce corresponding decreases in hinge moment requirements.

TABLE I. LOG OF CONFIGURATION AND TEST CONDITION SERIES A TEST (FULL SCALE TGSM)

CONFIGURATION	θ	δ_f	MACH NUMBERS
B.T.	0	0	.66*, .83*, .95*, 1.0*, 1.05*, 1.2*, 1.3
		7.5	Same
		-7.5	Same
		15	Same
		22.5	Same
		-15	.83, .95, 1.0, 1.05, 1.2, 1.3
		-22.5	Same
	22.5	0	Same
	45	0	.66, .83, .95, 1.0, 1.05, 1.2, 1.3
		7.5	Same
		-7.5	Same
		-15	Same
		-22.5	Same
		15	.83, .95, 1.0, 1.05, 1.2, 1.3
		22.5	1.0
B_1T_2	0	0	.83, .95, 1.0, 1.05, 1.2
		7.5	Same
		-7.5	.95, 1.0, 1.05, 1.2
		-15	Same
B_2T_1	0	0	.66*, .83*, .95*, 1.0*, 1.05*, 1.2*, 1.3*
		-7.5	.83, .95, 1.0, 1.05, 1.2
		-15.0	Same
	45	0	.95, 1.0
B_4T_1	0	0	Same
		-7.5	Same
B_5T_1	0	0	Same*
		-7.5	Same*
B_1	0	--	.95, 1.0, 1.05, 1.2, 1.3
	45	--	.95, 1.0, 1.05, 1.2
B_2	0	--	1.0
B_1T_{X1}	0		1.0
X2	0		1.0
X3	0		1.0
X4	0		1.0

*Data Presented Herein.

Where:

B_1 = body with open slots and open fin root chord region

B_2 = body without slots

B_4 = body with slots rear of fin root area closed

B_5 = body with only fin root area open, no body slots

T_1 = fins shown in Figure 1

T_2 = same fins partially deployed (72.5 degs)

X_n = cover panel rigidly attached to TGSM at a designated location

θ = TGSM roll position

δ_f = fins deflection angle, measured from body centerline

TABLE II. LOG OF CONFIGURATIONS AND TEST CONDITIONS, SERIES B TEST (1/4 SCALE TGSM/PANEL, M=1.0)

Configurations	α_s	α_p	Δx	Δz
B_1T_1, B_1T_3	-.5/36°	--	--	--
"	-5	0	Variable	Variable
* "	0			
"	5			
"	10			
* ---	15			
* ---	20			
"	-5	-5		
"	0			
"	5			
---	10			
---	15			
---	20			
"	-10	-10		
"	-5			
"	0			
---	5			
---	10			
"	5	5		
"	10			
---	15			
"	10	10		
---	15			
---	20			
---	0	-20		
---	-5			

Where: B_1 = 1/4 Scale TGSM (solid body)
T_1 = 1/4 Scale fins, shown in Figure 1 , (4 fins)
T_3 = same fin geometry but fins at 45° and 315° removed (2 fins)
α_s = submissile angle-of-attack
α_p = cover panel angle-of-attack
Δx = See Figure 2, horizontal separation of cg of bodies
Δz = See Figure 2, vertical separation of cg of bodies

*Plotted Data shown herein

Data from the B Series test is presented in Figures 7 and 8. The test article's details and test positions investigated are shown in Figure 2.

Data in Figure 7 are selected to illustrate the influences imparted to the TGSM by a typical cover panel at various locations in the vertical and horizontal planes. To aid in visualizing the relative positions of these two bodies, a schematic showing the panel in the two extreme horizontal locations is included. It is pointed out that no attempt was made to duplicate any additional changes in flowfield which might be induced by the presence of a carrier missile.

The changes in TGSM forces and moments produced at the panel are shown in Figure 7. The disturbing force imparted by the panel is roughly equivalent to changing the TGSM's angle of attack by four degrees at some TGSM/panel horizontal positions tested.

The force as well as the moment response shown in Figure 7b are seen to be highly dependent on the horizontal positions of the two bodies (Δx). These horizontal position changes produce both magnitude and directional changes in recorded forces and moments. The erratic nature of these parameters make difficult any characterization of the results as a function of horizontal positions and appear to be best described in an empirical manner.

The variation of the forces and moments with vertical position changes, ΔZ, are seen to be a more predictable response. As expected, an increase in distance between bodies produce a lessening of the mutual interference. Test data was not obtained at a sufficiently large separation to determine the ΔZ distance at which the influence becomes negligible.

Figure 8 presents the force and moment acting on the TGSM at angles of attack in the presence of a cover panel. These data were obtained as ΔX distances were changed but at a constant ΔZ separation. These data show the pitched TGSM responses to the panel's presence to be similar to the zero angle of attack cases over the ΔX ranges investigated. However, the data obtained at TGSM angles of attack show a consistent decrease in TGSM normal force and a corresponding decrease in restoring pitching moment when a comparison is made with data obtained at similar attitudes on the TGSM model with no panel present.

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1. High Speed Wind Tunel Data Report, NSWT Test 798, Vought Corporation, Dallas, TX 1983.

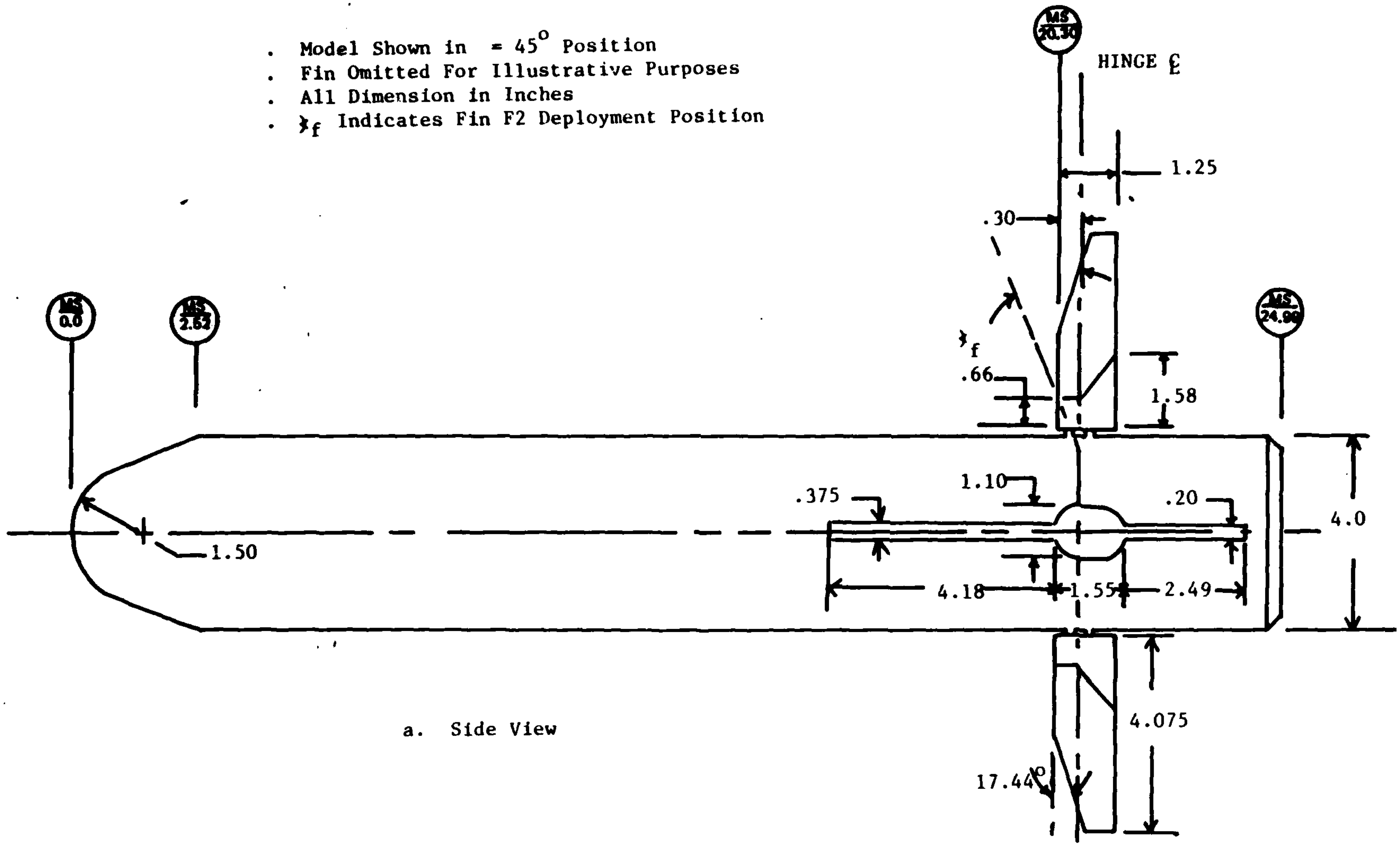
2. High Speed Wind Tunnel Data Report, NSWT Test 802, Vought Corporation, Dallas, TX 1983.

3. Barnett, E., "Assault Breaker Panel/TGSM Wind Tunnel Testing, A-3355FR" Georgia Institute of Technology, Atlanta, GA 1983.

4. Singleton, R., et al., "User's Guide for Assault Breaker/Terminally Guided Submissile (TGSM's) Data Base," US Army Missile Command, 1983.

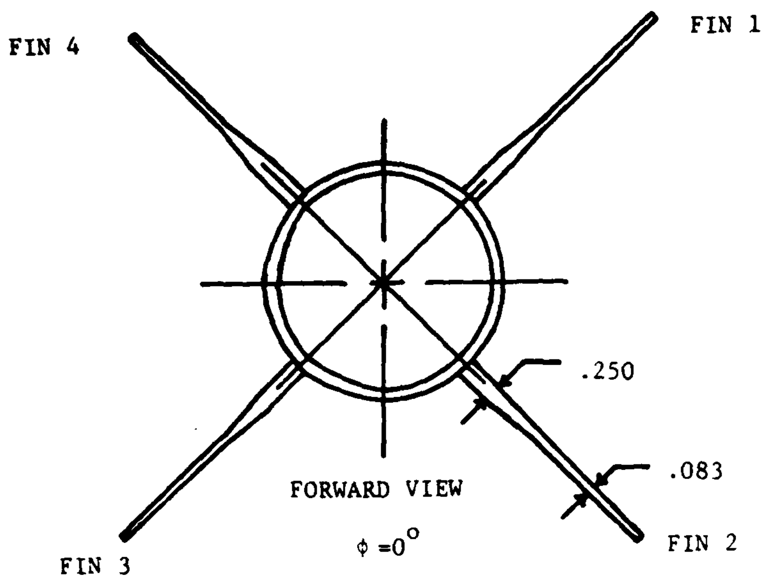
5. Arnold, J. W., "High Speed Wind Tunnel Facilities Handbook" Publication No. AER-EIR-13552D, Vought Corporation, Dallas, TX, Jan 1980.

. Model Shown in = 45° Position
. Fin Omitted For Illustrative Purposes
. All Dimension in Inches
. γ_f Indicates Fin F2 Deployment Position



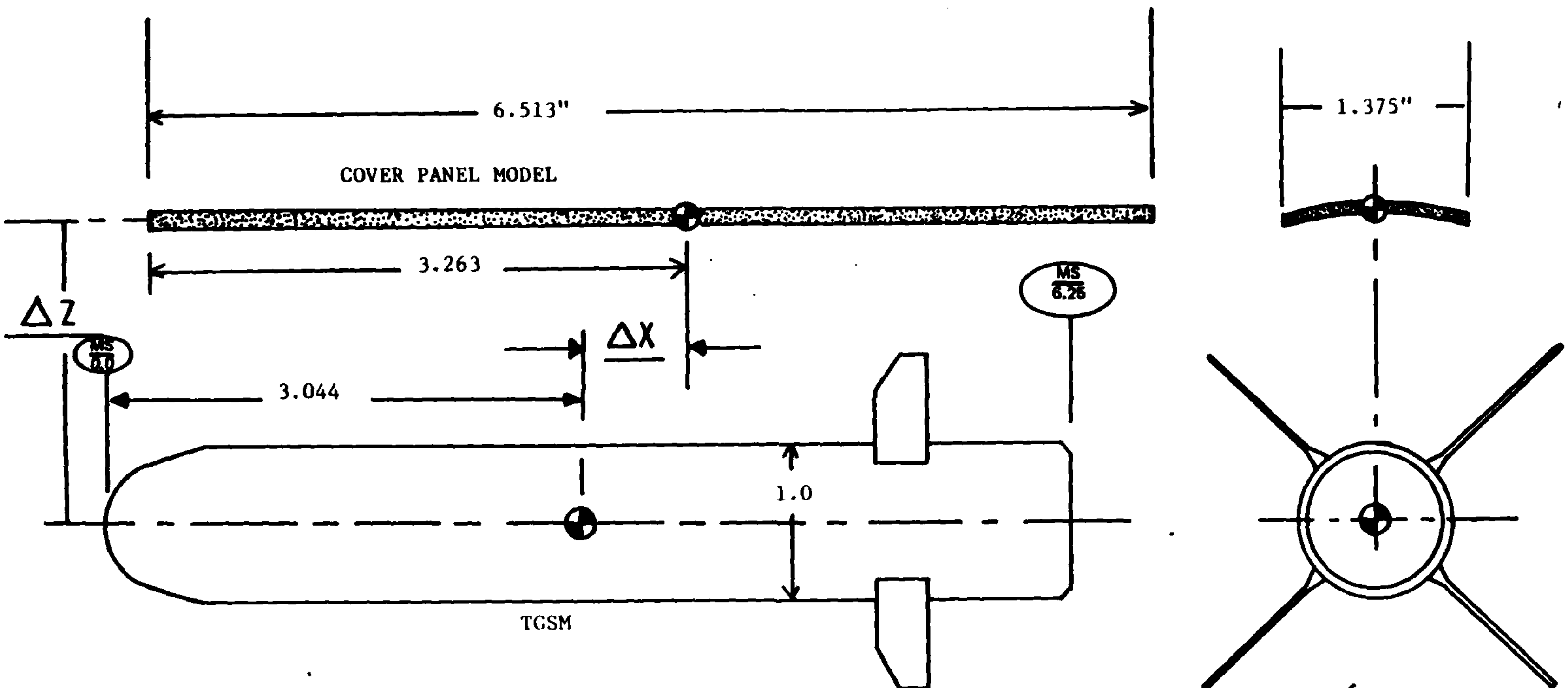
a. Side View

Figure 1. Series A test model details.



b. Rear View

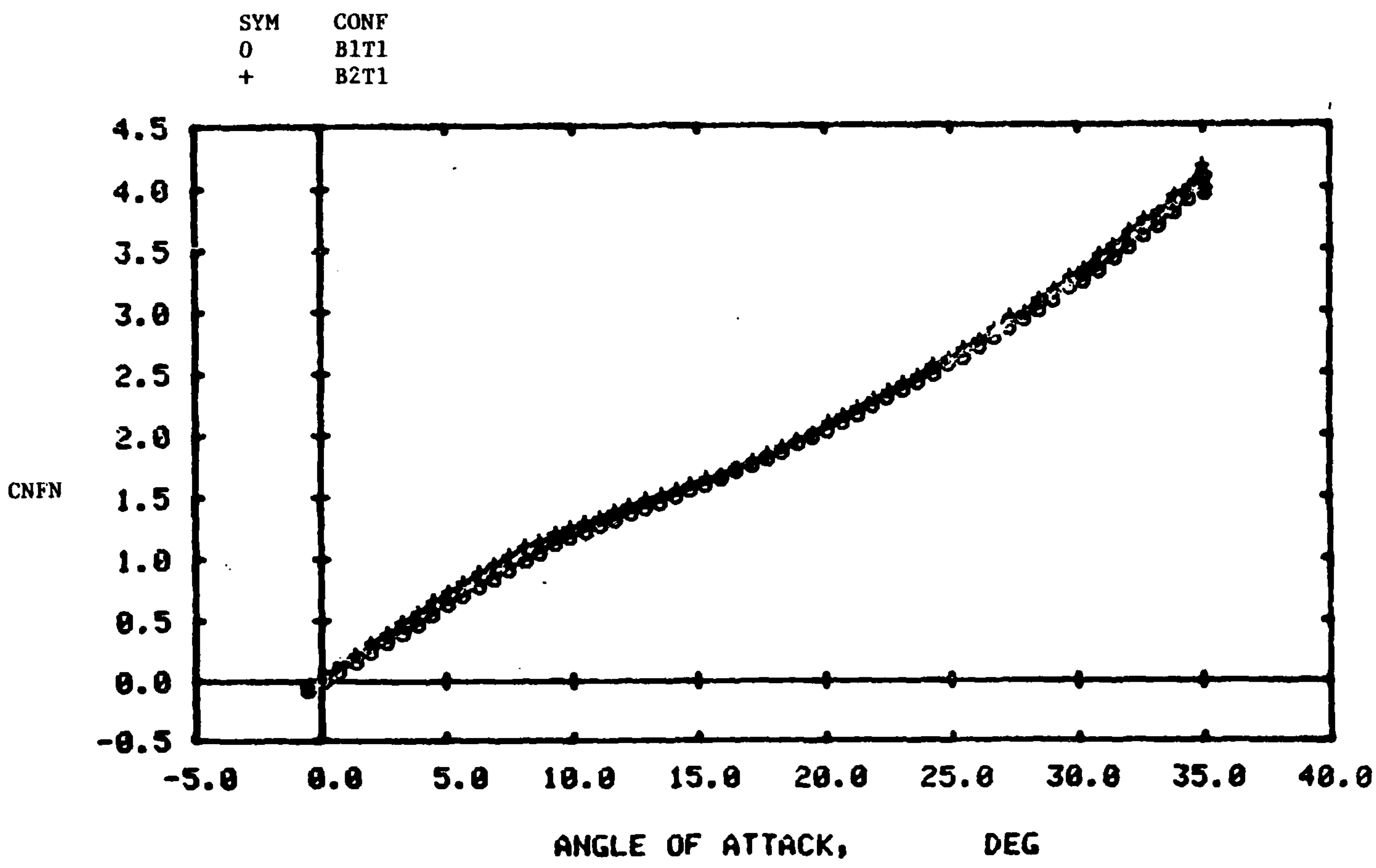
Figure 1. Series A test model details (concluded).



(No Body Slots)

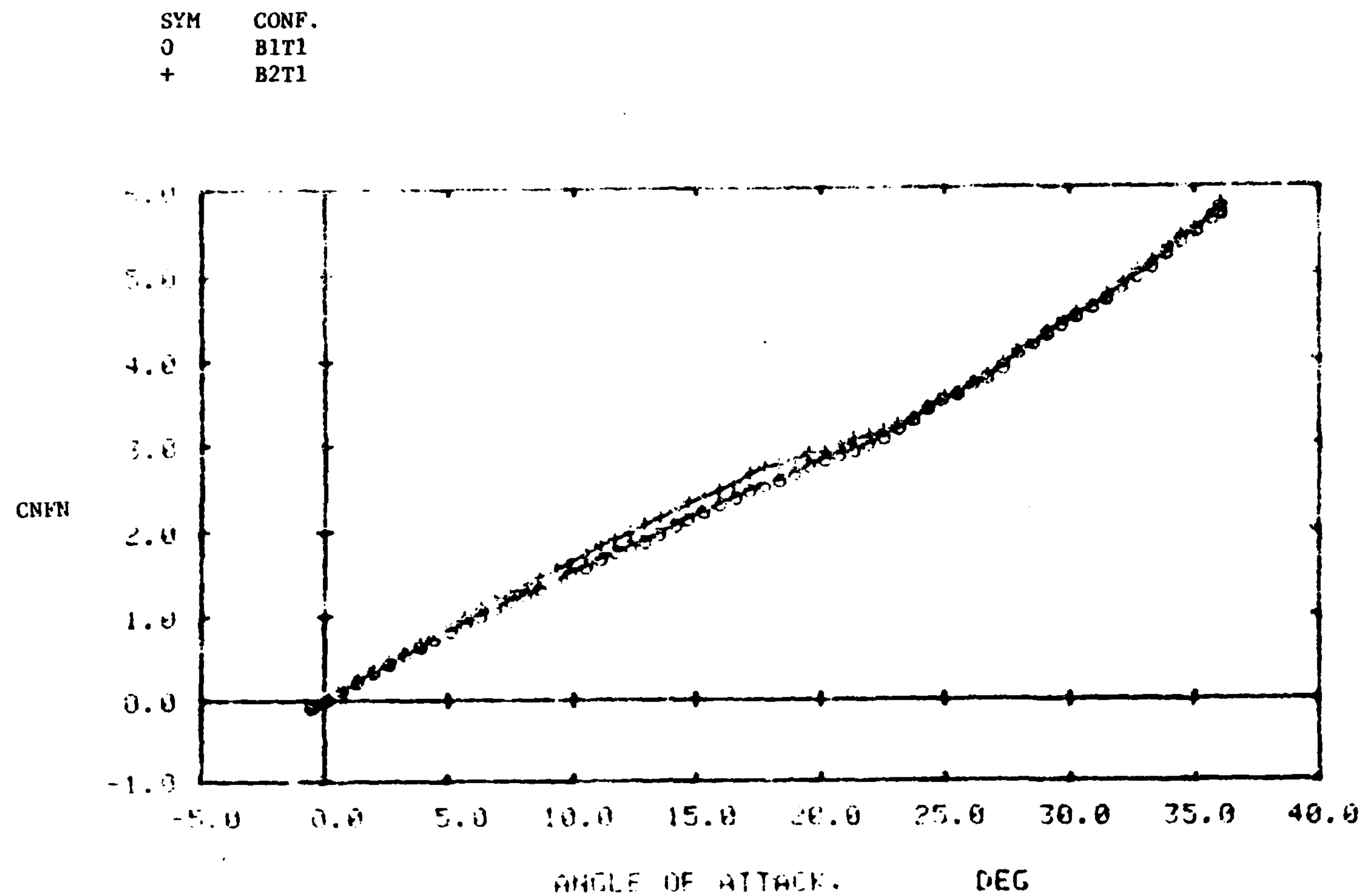
(1/4 Scale, See Fig 1 for Full Scale Dimensions)

Figure 2. Series B test models details.



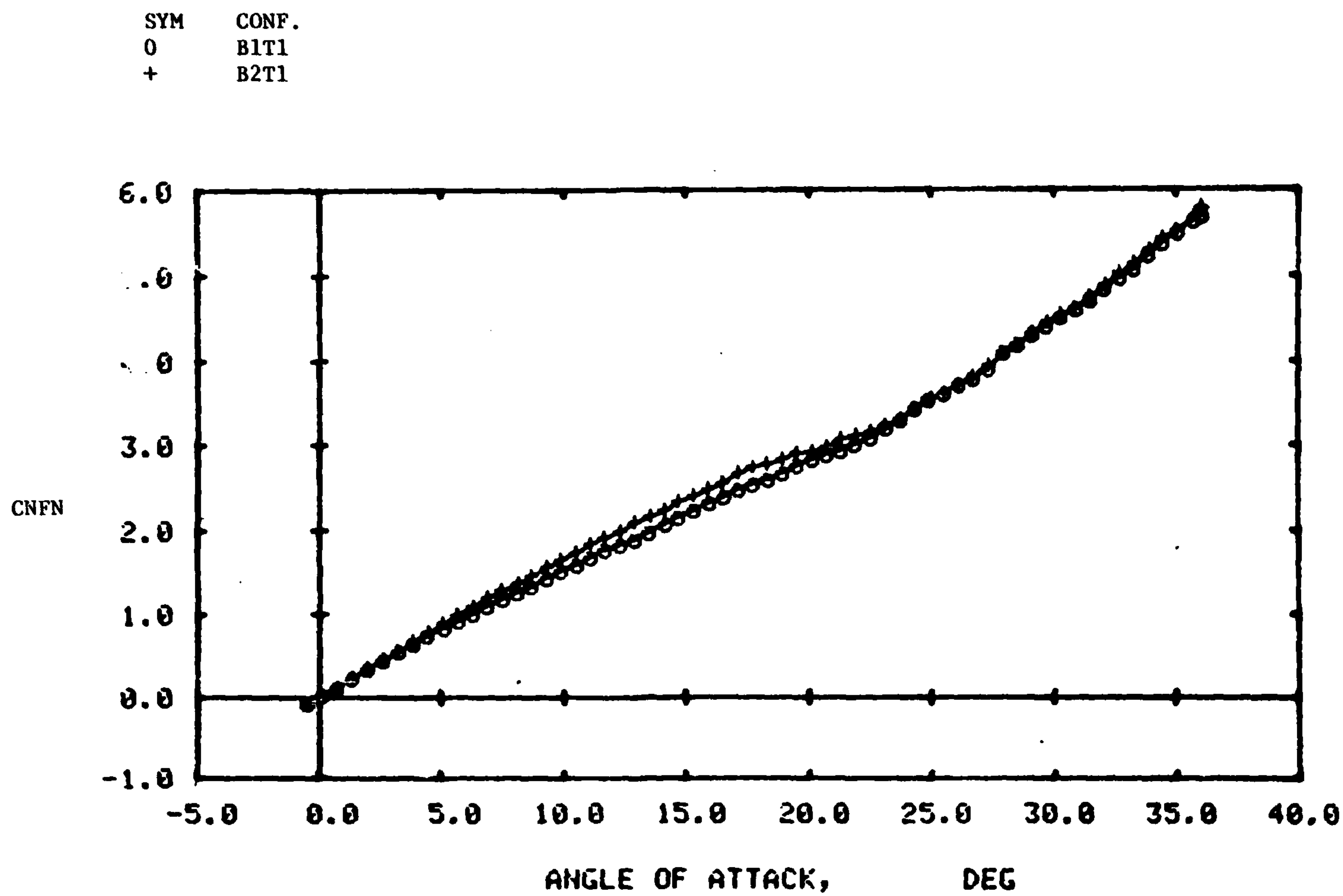
a. Normal Force Coefficient vs Angle of Attack, M=0.66

Figure 3. Effect of body slots on submissile total normal force.



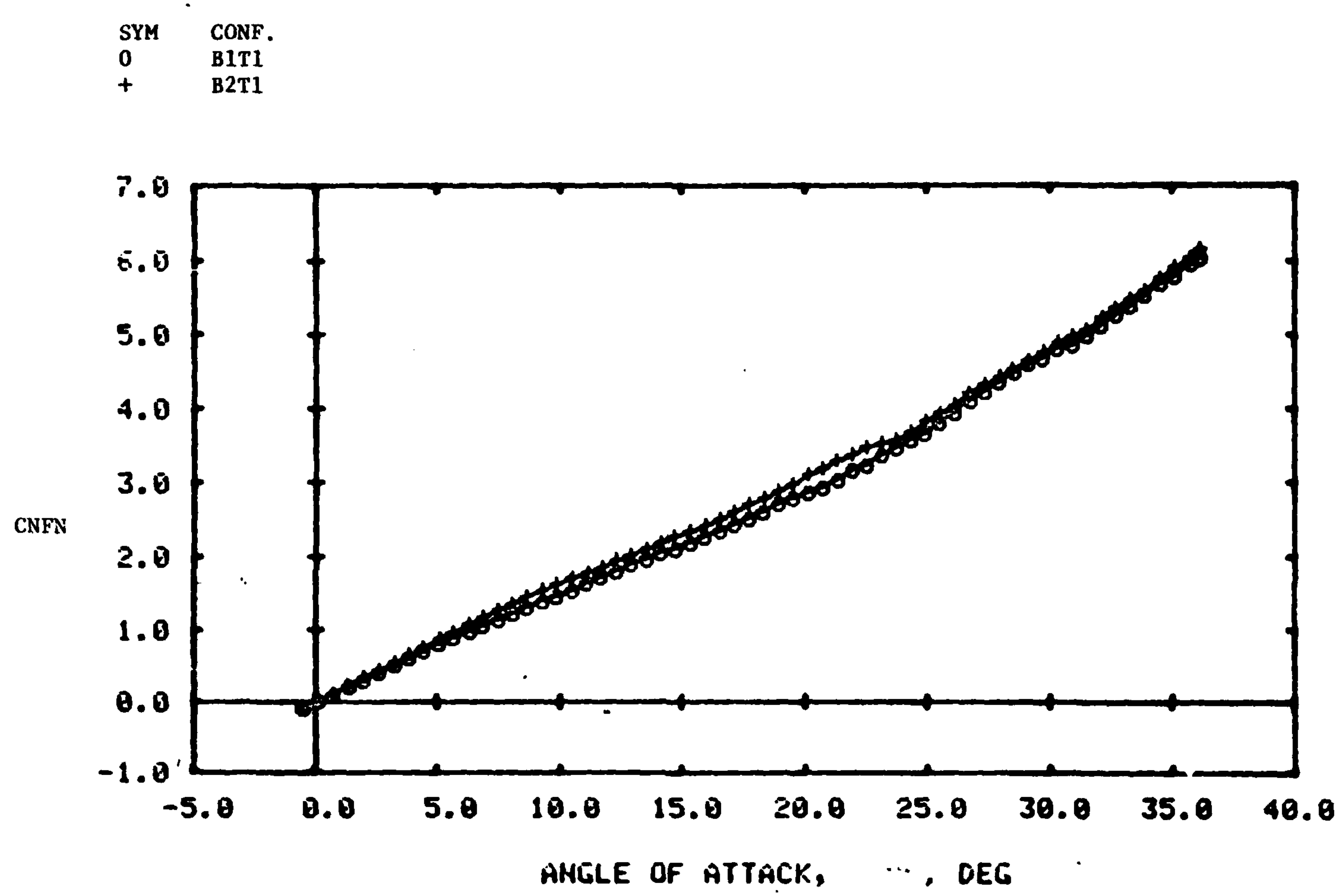
b. Normal Force Coefficient vs Angle of Attack, M=0.83.

Figure 3. Effect of body slots on submissile total normal force (continued).



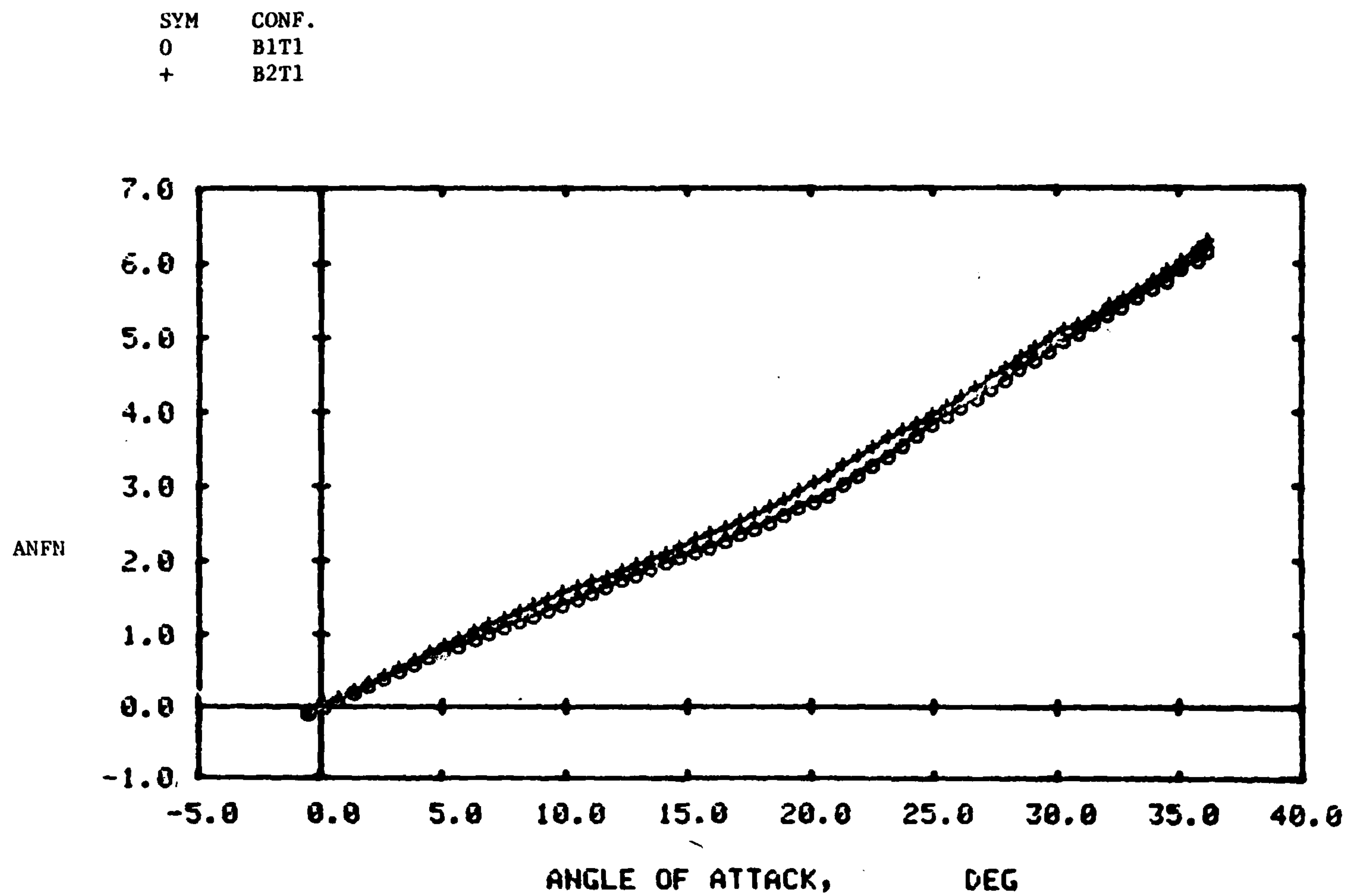
c. Normal Force Coefficient vs Angle of Attack, M=0.95.

Figure 3. Effect of body slots on submissile total normal force (continued).



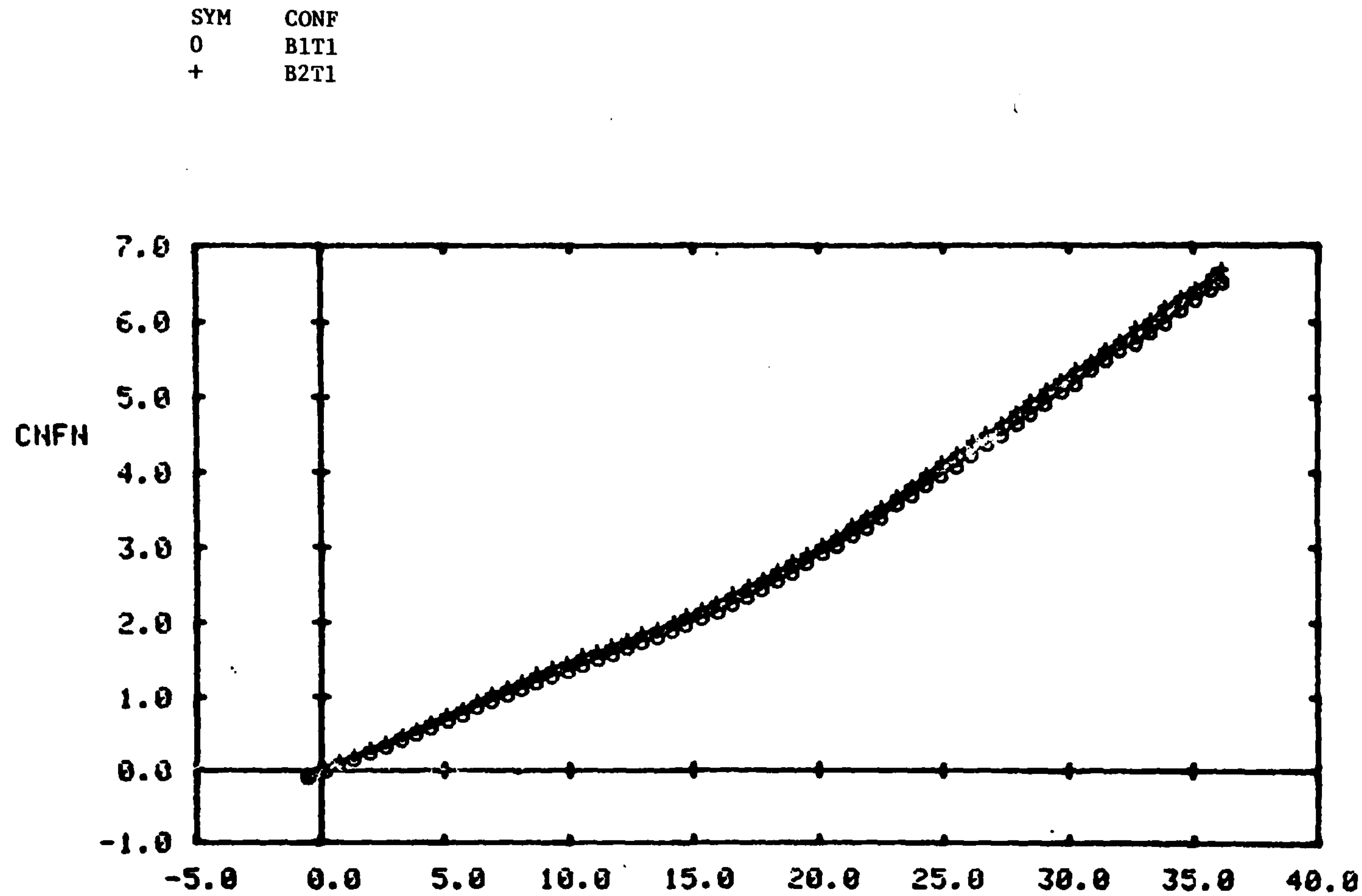
d. Normal Force Coefficient vs Angle of Attack, M=1.0.

Figure 3. Effect of body slots on submissile total normal force (continued).



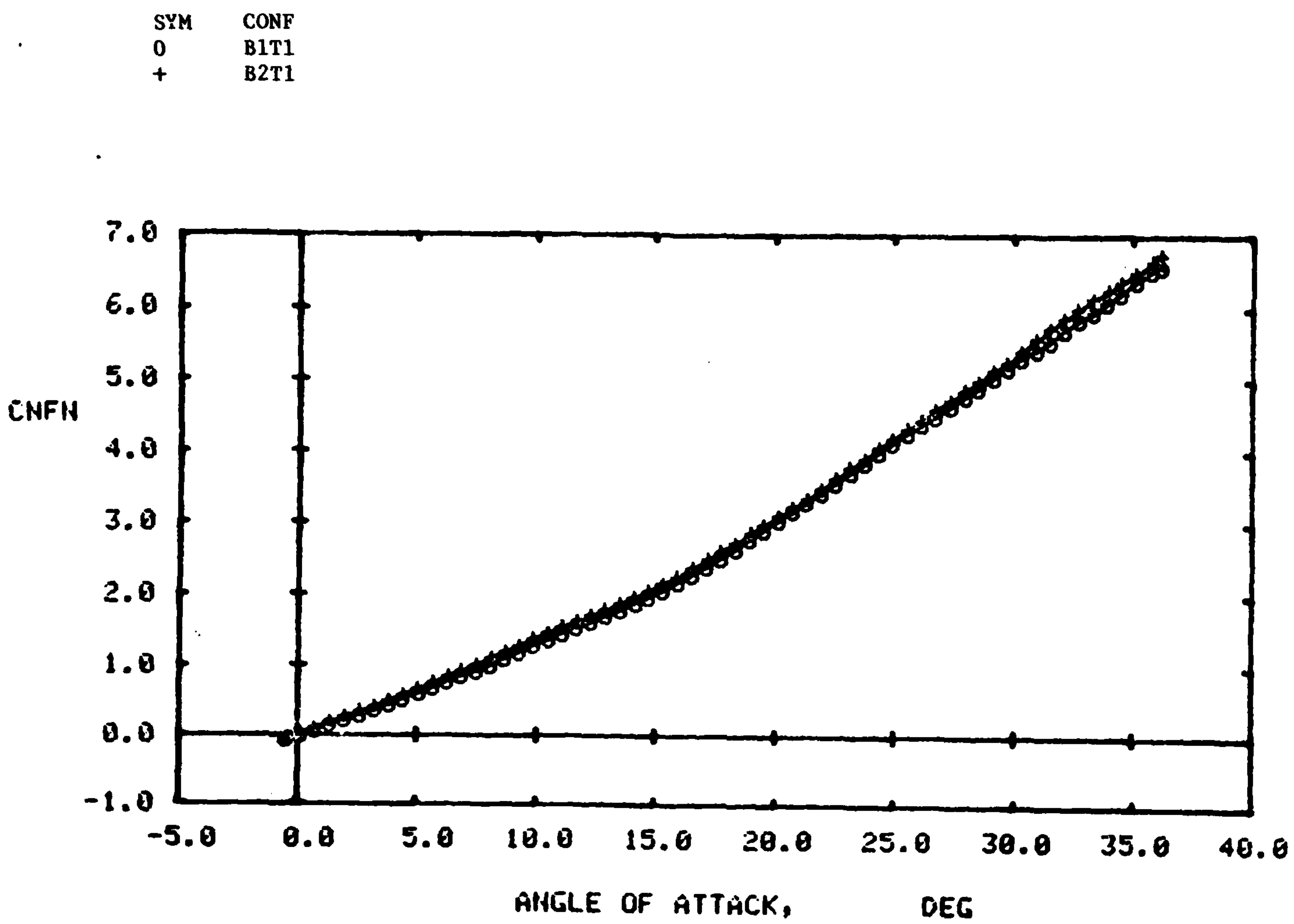
e. Normal Force Coefficient vs Angle of Attack, M=1.05.

Figure 3. Effect of body slots on submissile total normal force (continued).



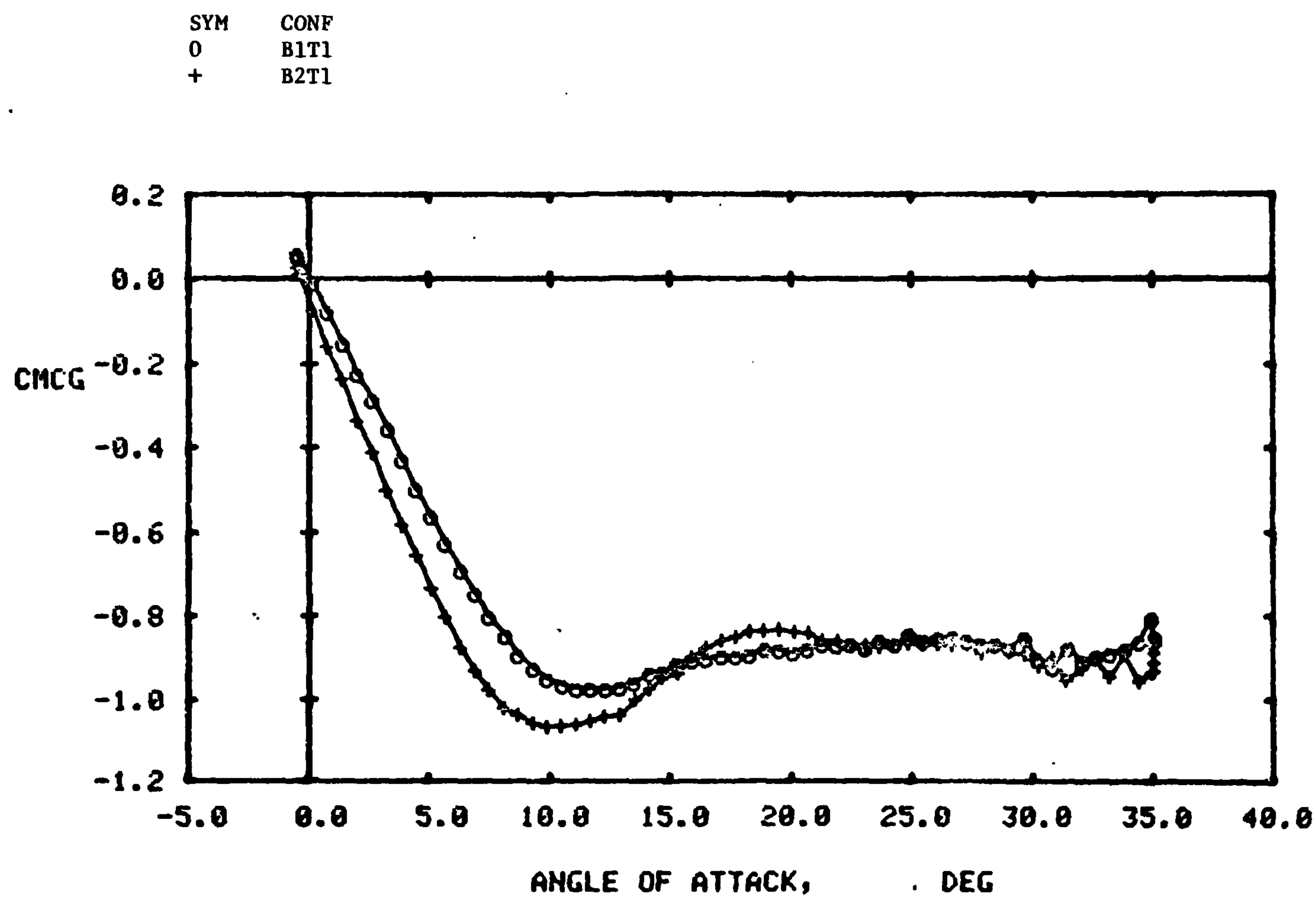
f. Normal Force Coefficient vs Angle of Attack, M=1.20.

Figure 3. Effect of body slots on submissile total normal force (continued).



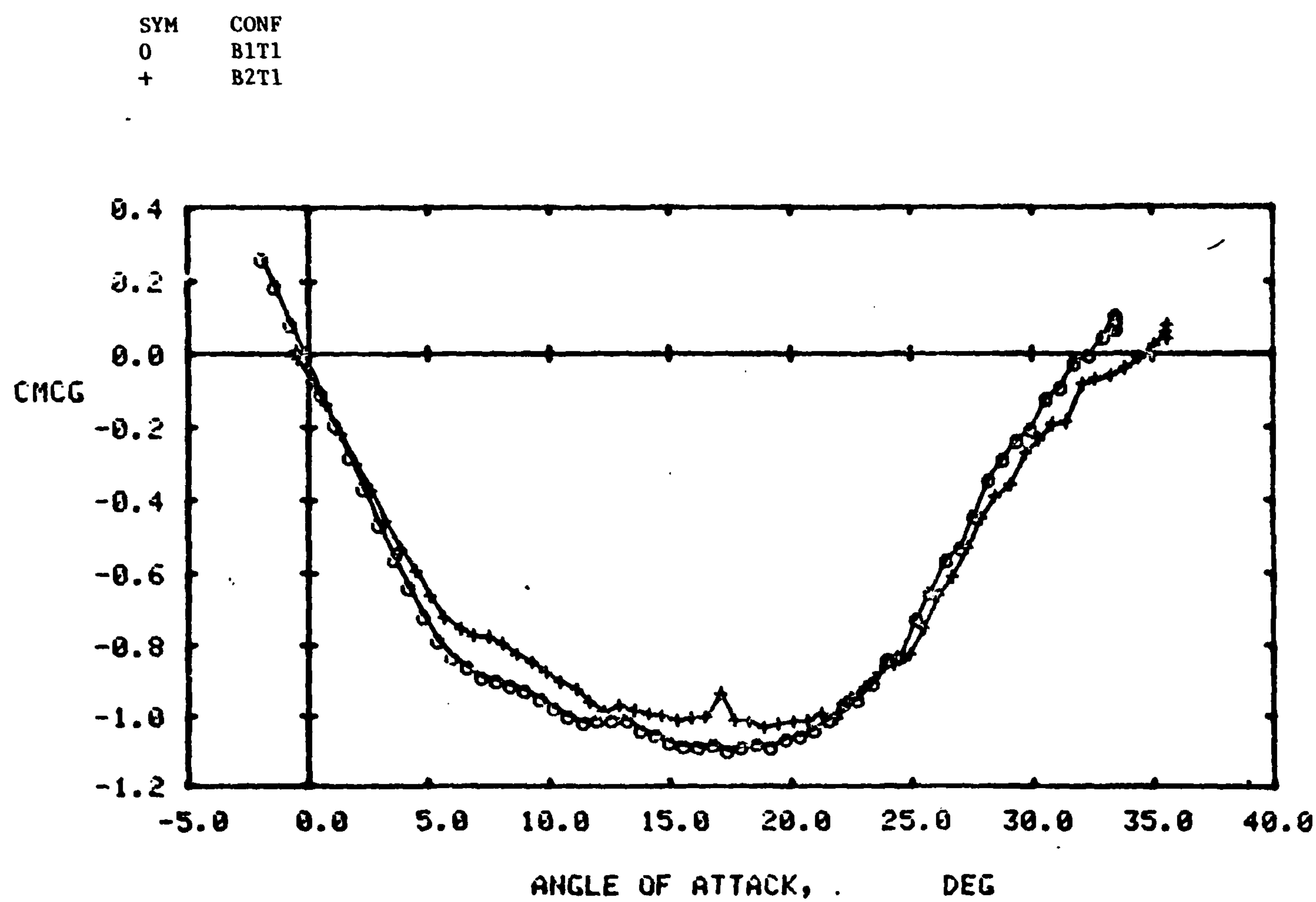
g. Normal Force Coefficient vs Angle of Attack, $M=1.30$.

Figure 3. Effect of body slots on submissile total normal force (concluded).



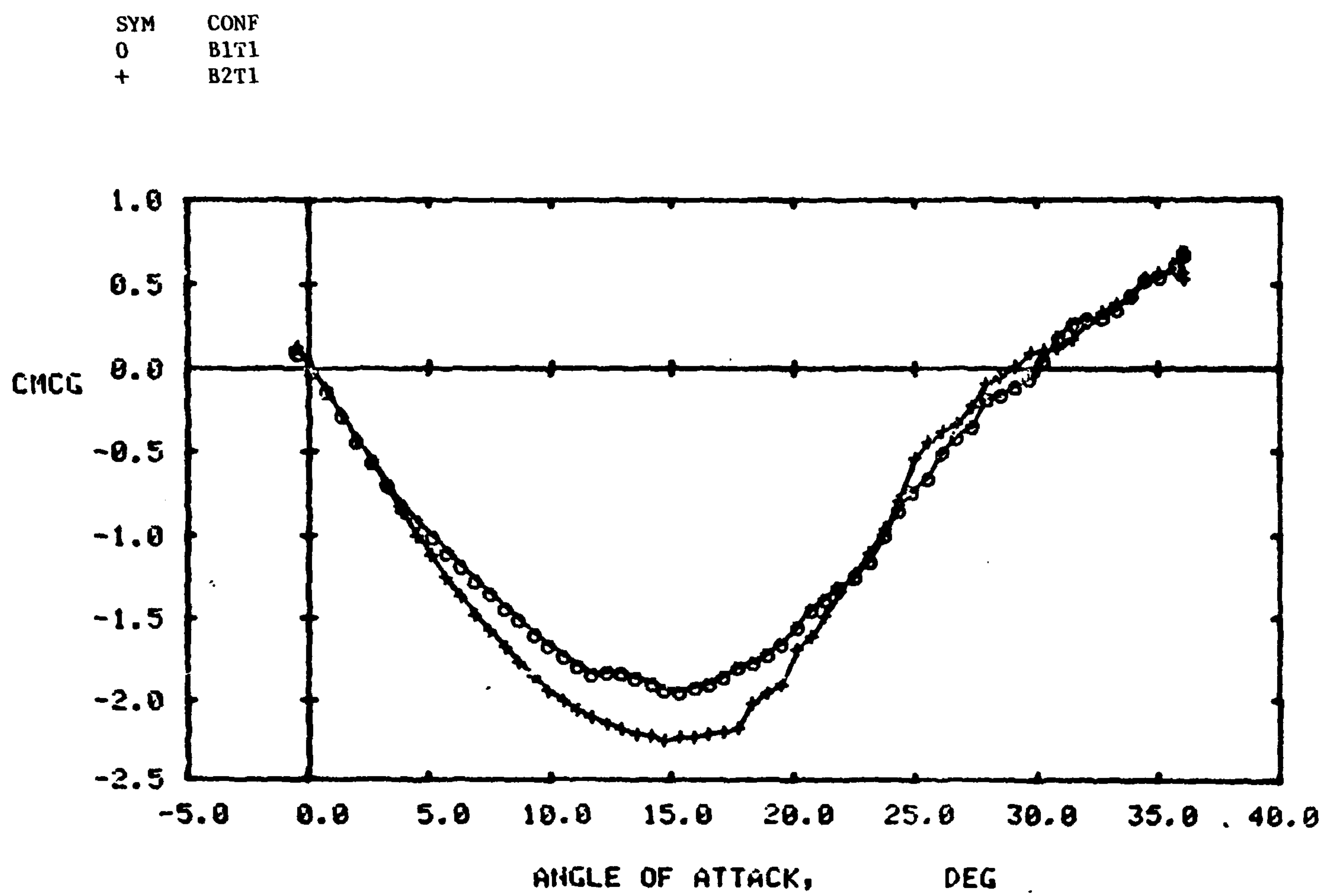
a. Pitching Moment Coefficient vs Angle of Attack, M=0.66.

Figure 4. Effect of body slots on submissile stability.



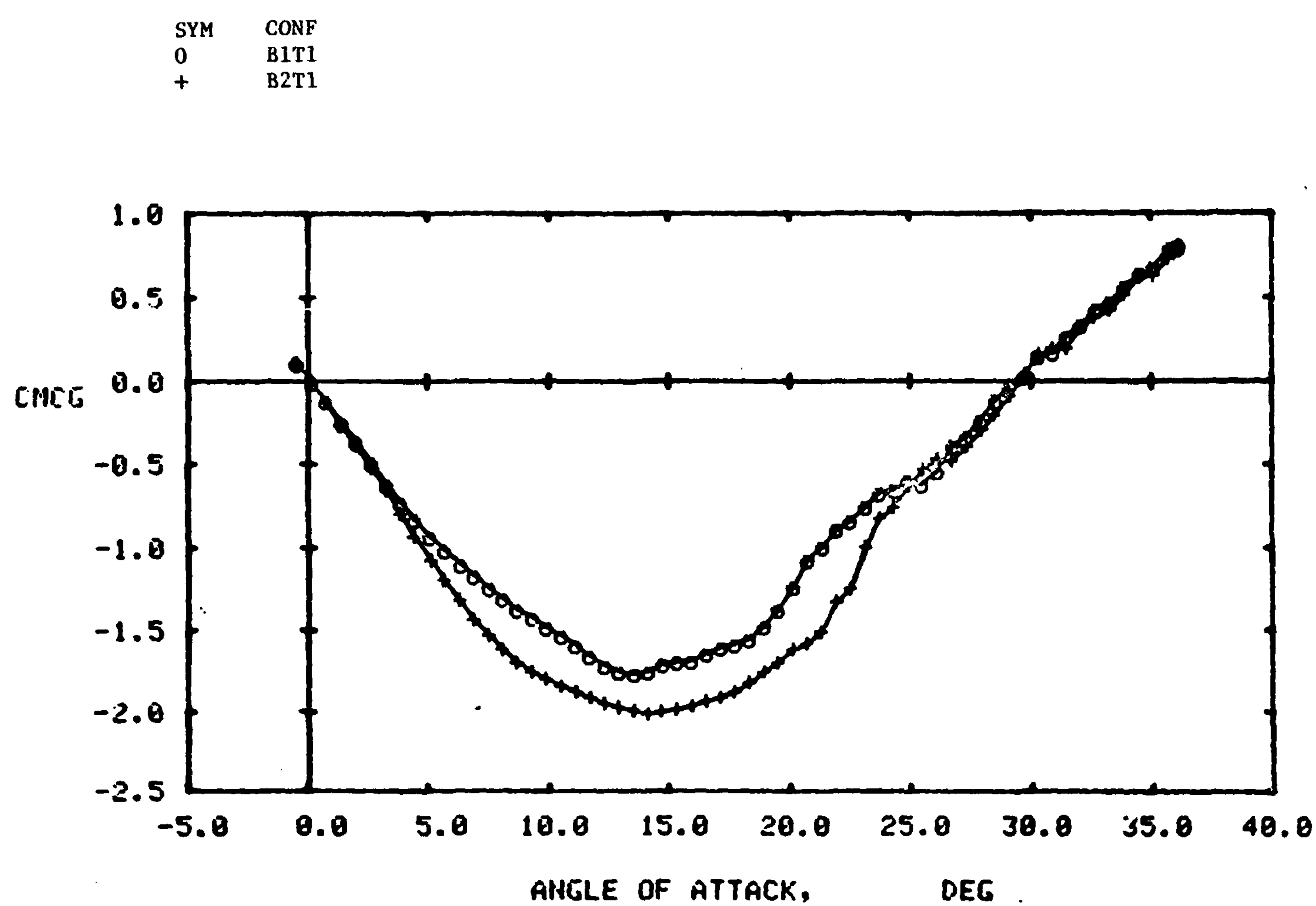
b. Pitching Moment Coefficient vs Angle of Attack, M=0.83.

Figure 4. Effect of body slots on submissile stability (continued).



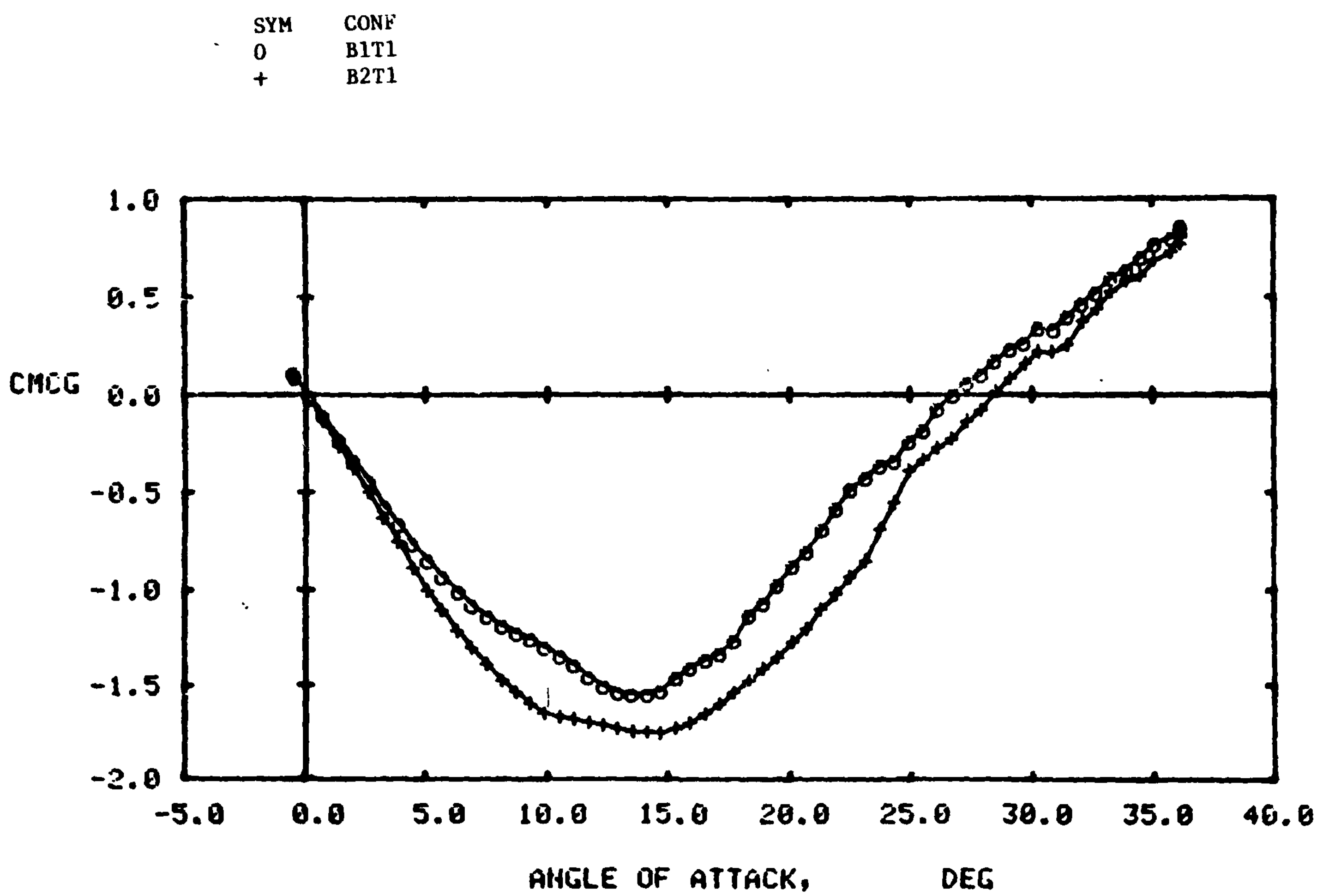
c. Pitching Moment Coefficient vs Angle of Attack, M=0.95.

Figure 4. Effect of body slots on submissile stability (continued).



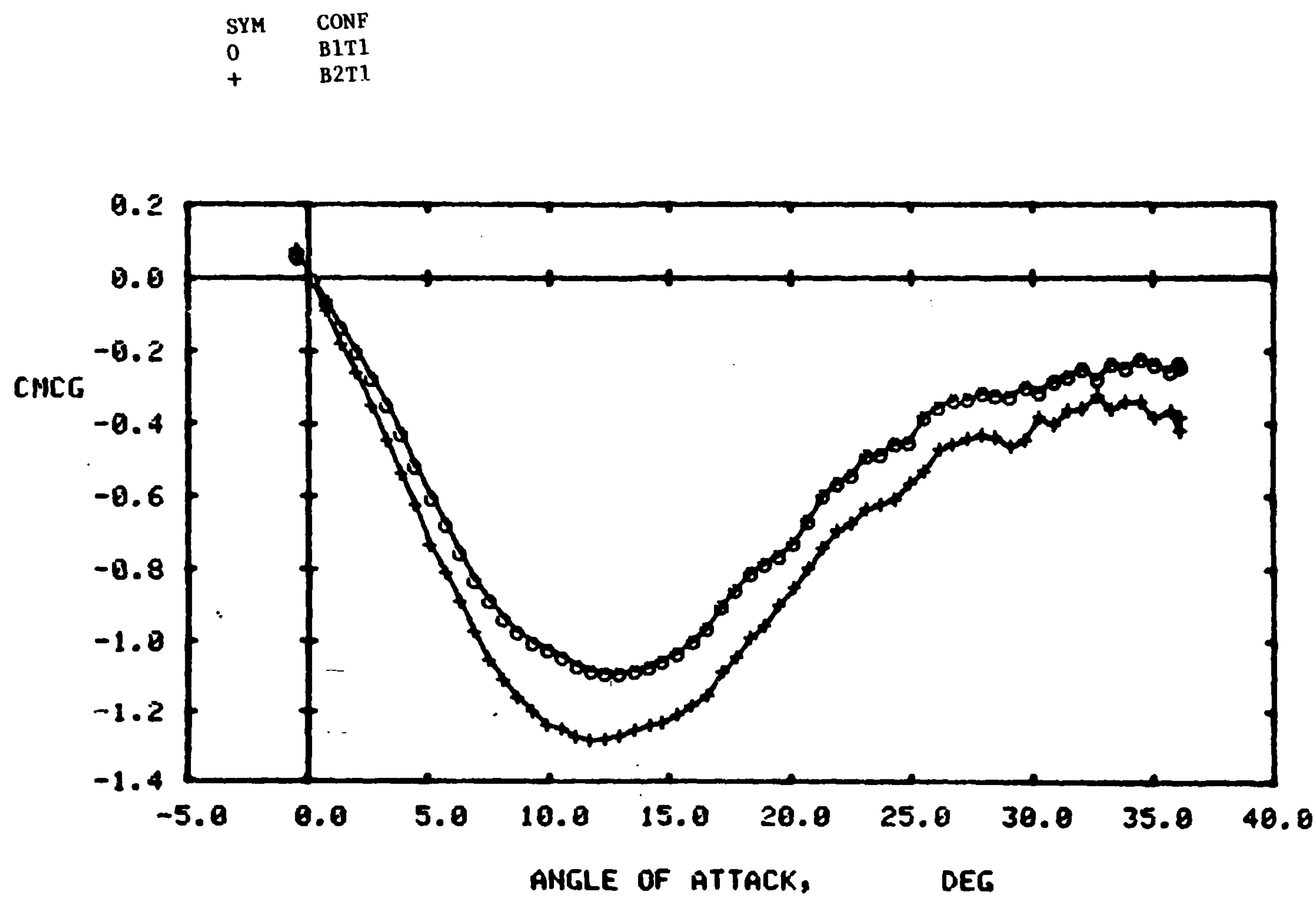
d. Pitching Moment Coefficient vs Angle of Attack, M=1.0.

Figure 4. Effect of body slots on submissile stability (continued).



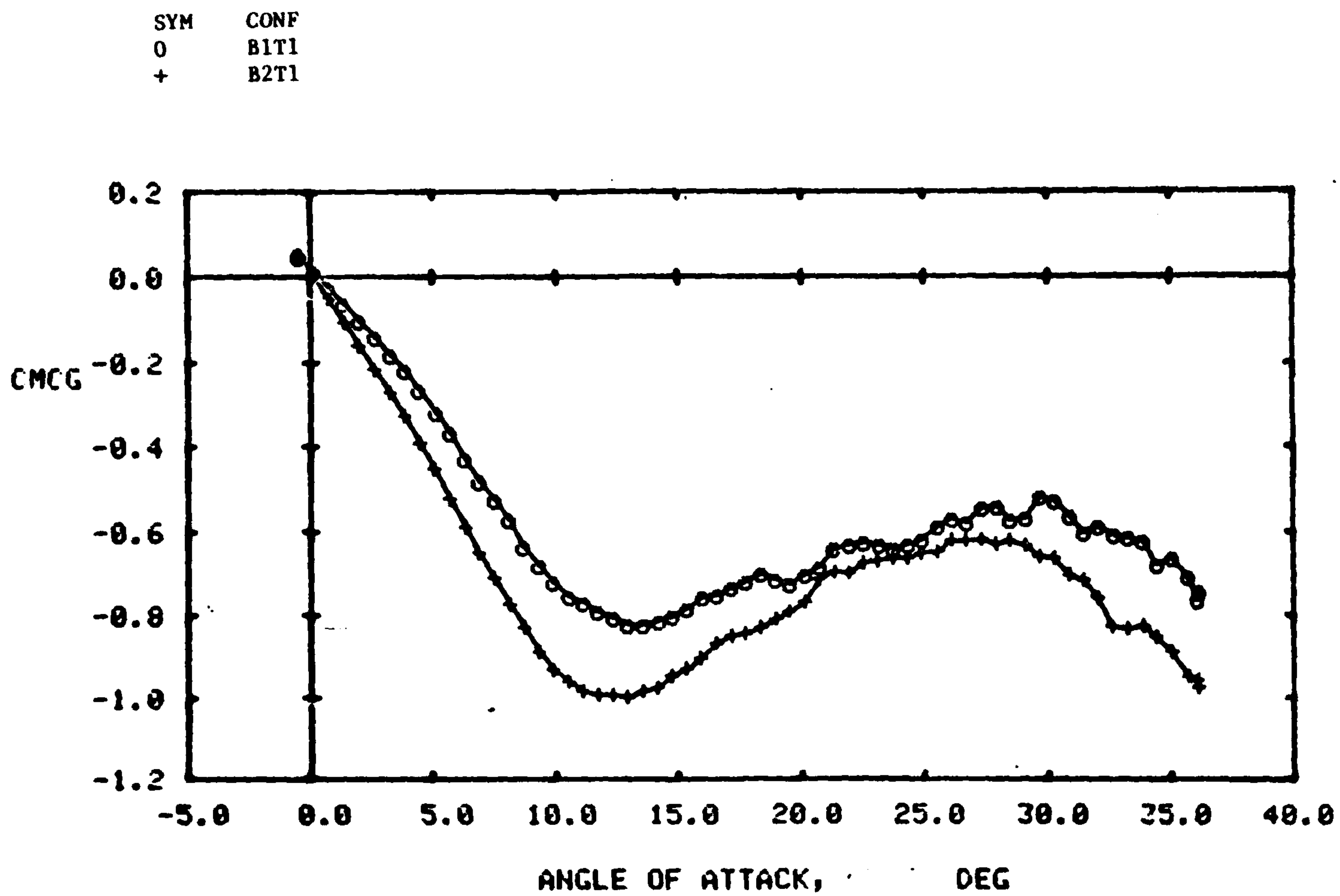
e. Pitching Moment Coefficient vs Angle of Attack, M=1.05.

Figure 4. Effect of body slots on submissile stability (continued).



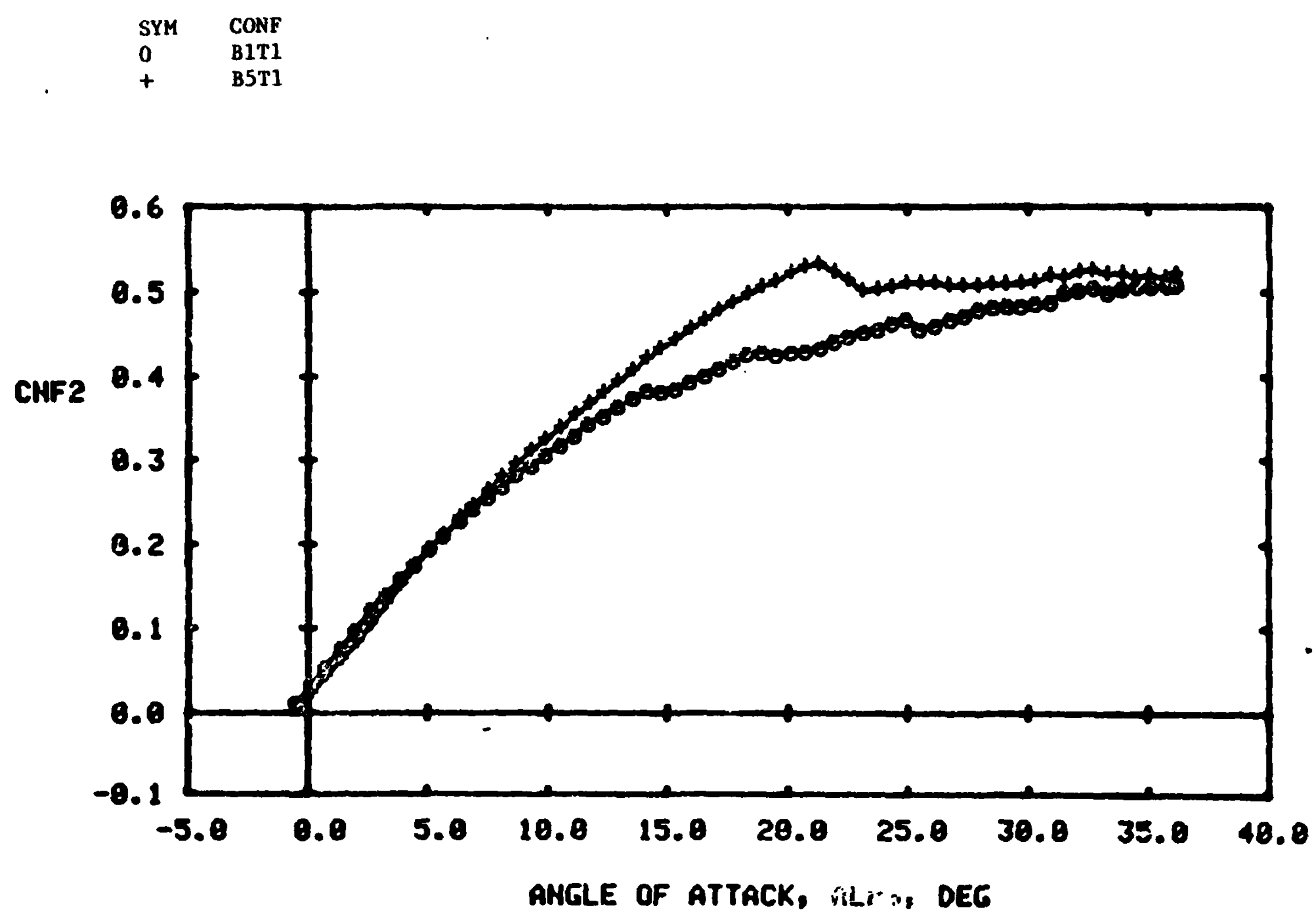
f. Pitching Moment Coefficient vs Angle of Attack, M=1.20.

Figure 4. Effect of body slots on submissile stability (continued).



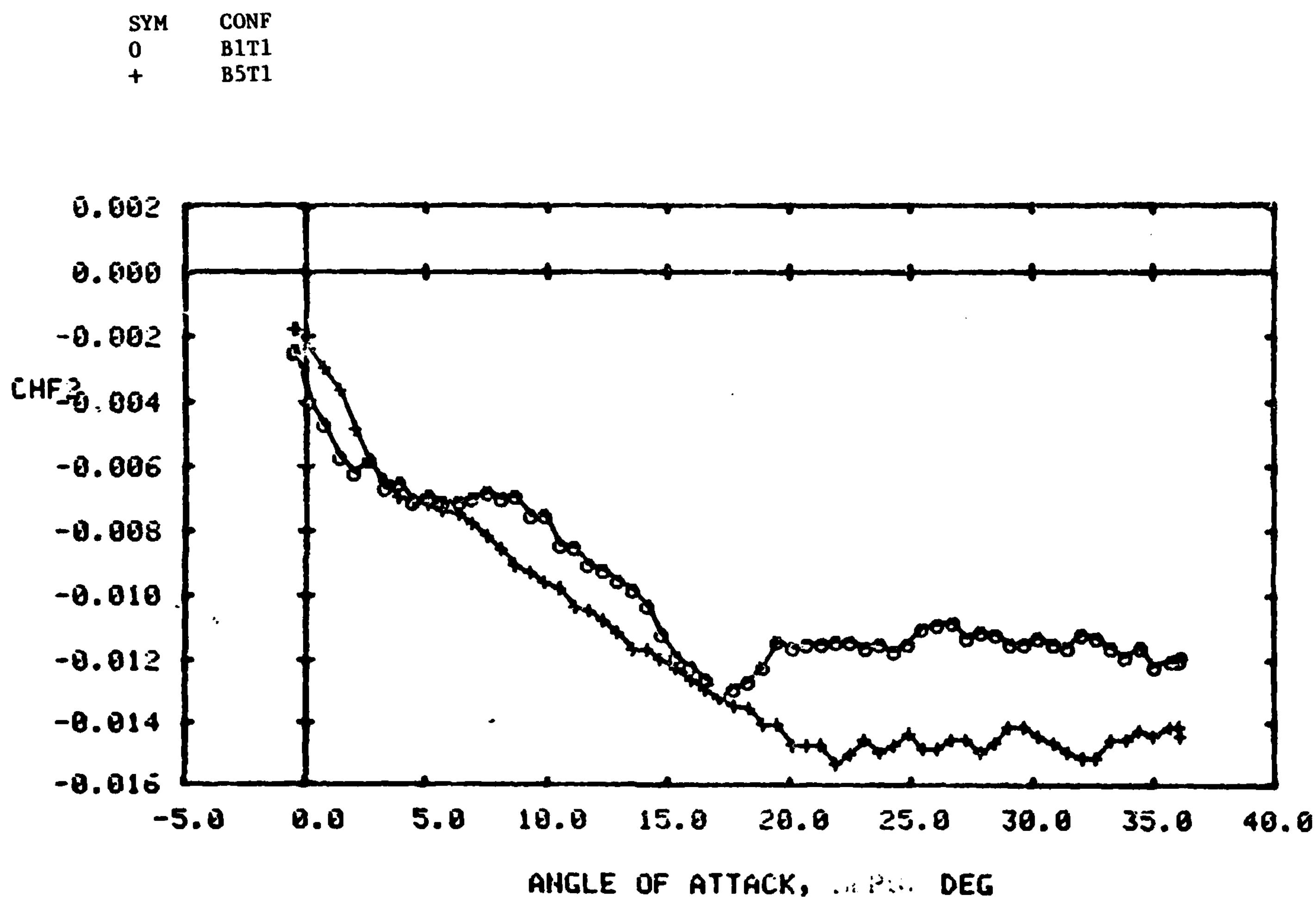
g. Pitching Moment Coefficient vs Angle of Attack, M=1.30.

Figure 4. Effect of body slots on submissile stability (concluded).



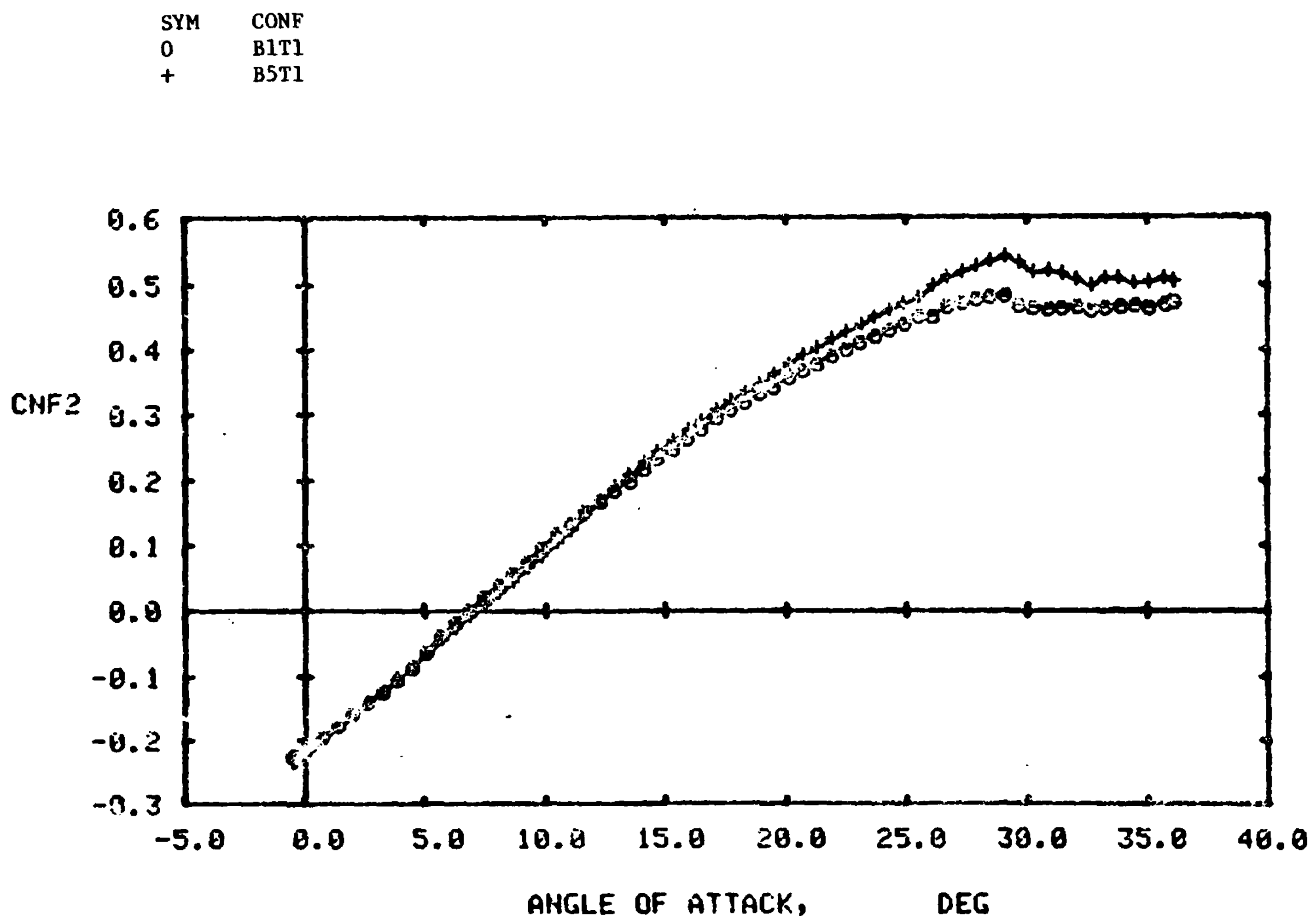
a. Normal Force Coefficient vs Angle of Attack, $\delta f = 0$.

Figure 5. Effect of body slots on wind ward fin loads.



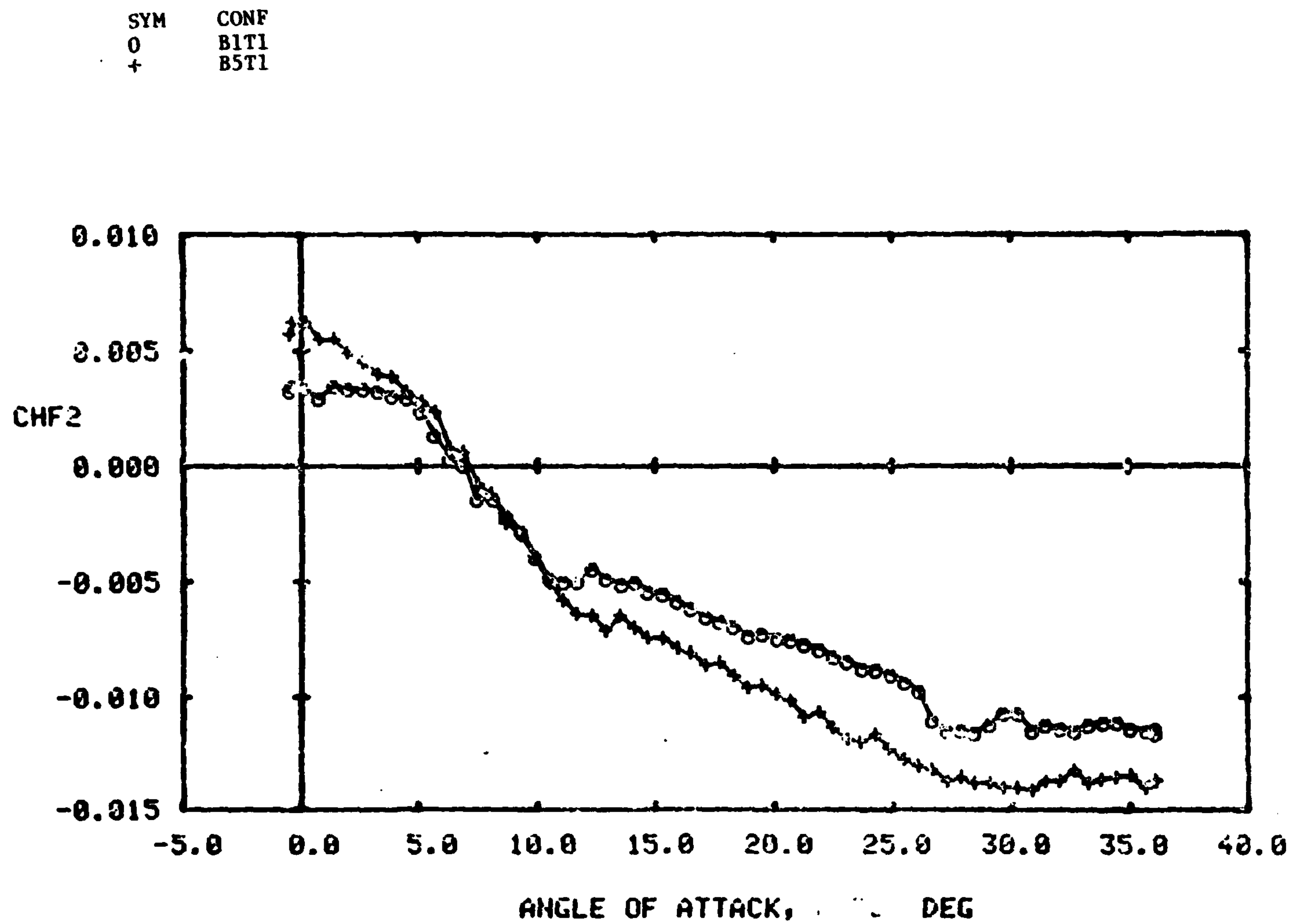
b. Hinge Moment Coefficient vs Angle of Attack, $\delta_f = 0$.

Figure 5. Effect of body slots on windward fin loads (continued).



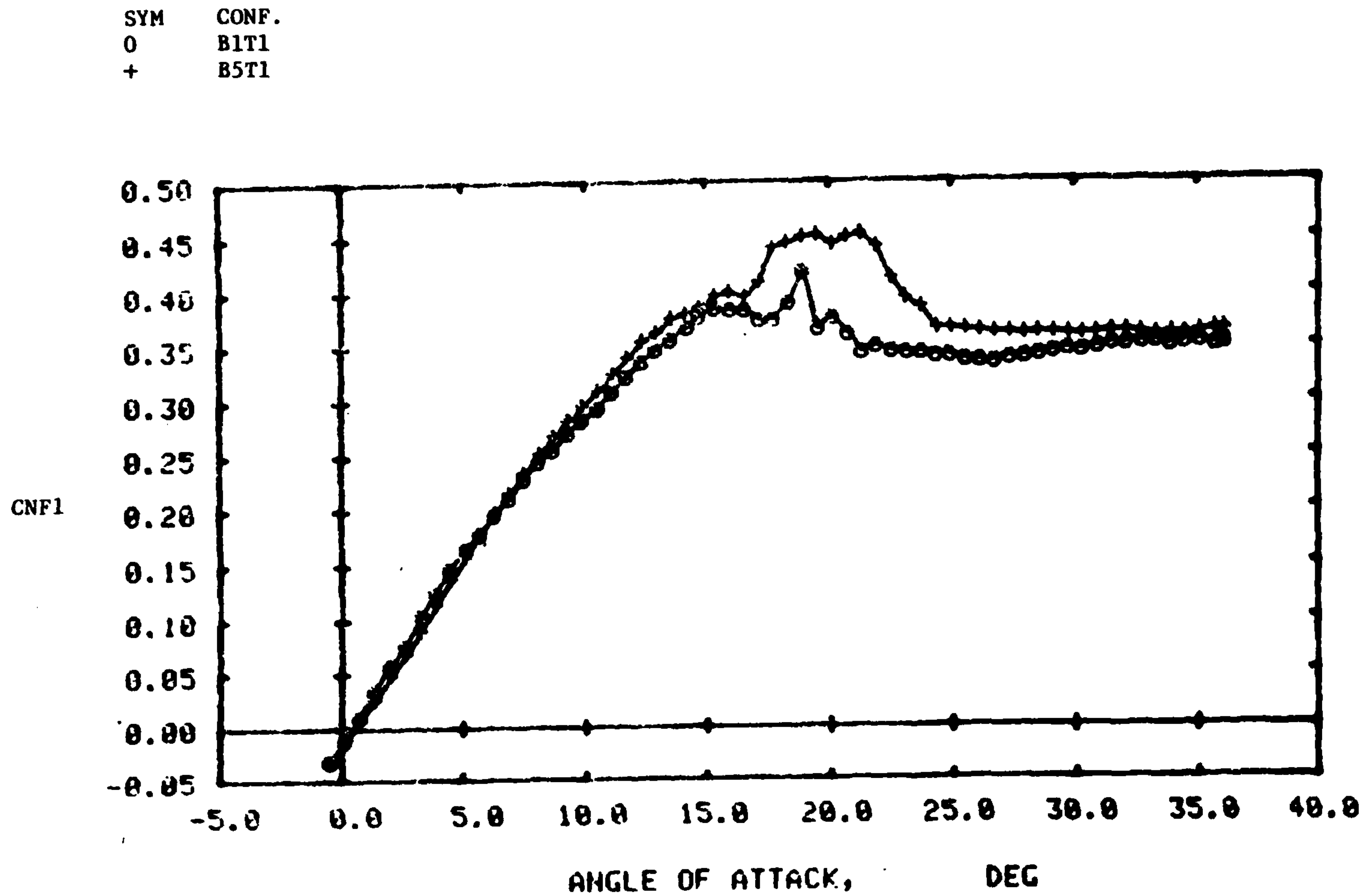
c. Normal Force Coefficient vs Angle of Attack, $\delta_f = -7.5^{\circ}$.

Figure 5. Effect of body slots on windward fin loads (continued).



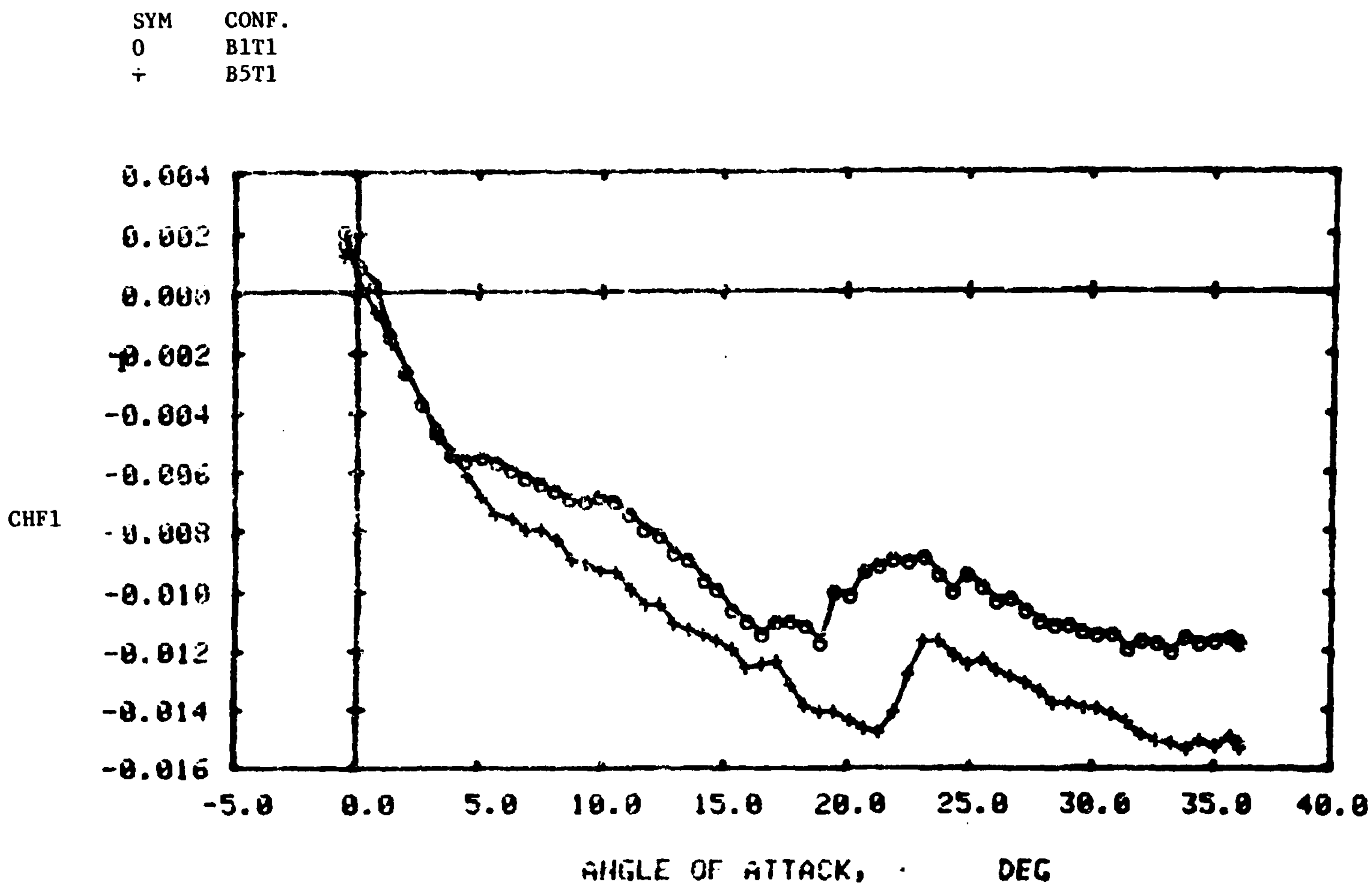
d. Hinge Moment Coefficient vs Angle of Attack, $\delta f = -7.5^{\circ}$.

Figure 5. Effect of body slots on windward fin loads (continued).



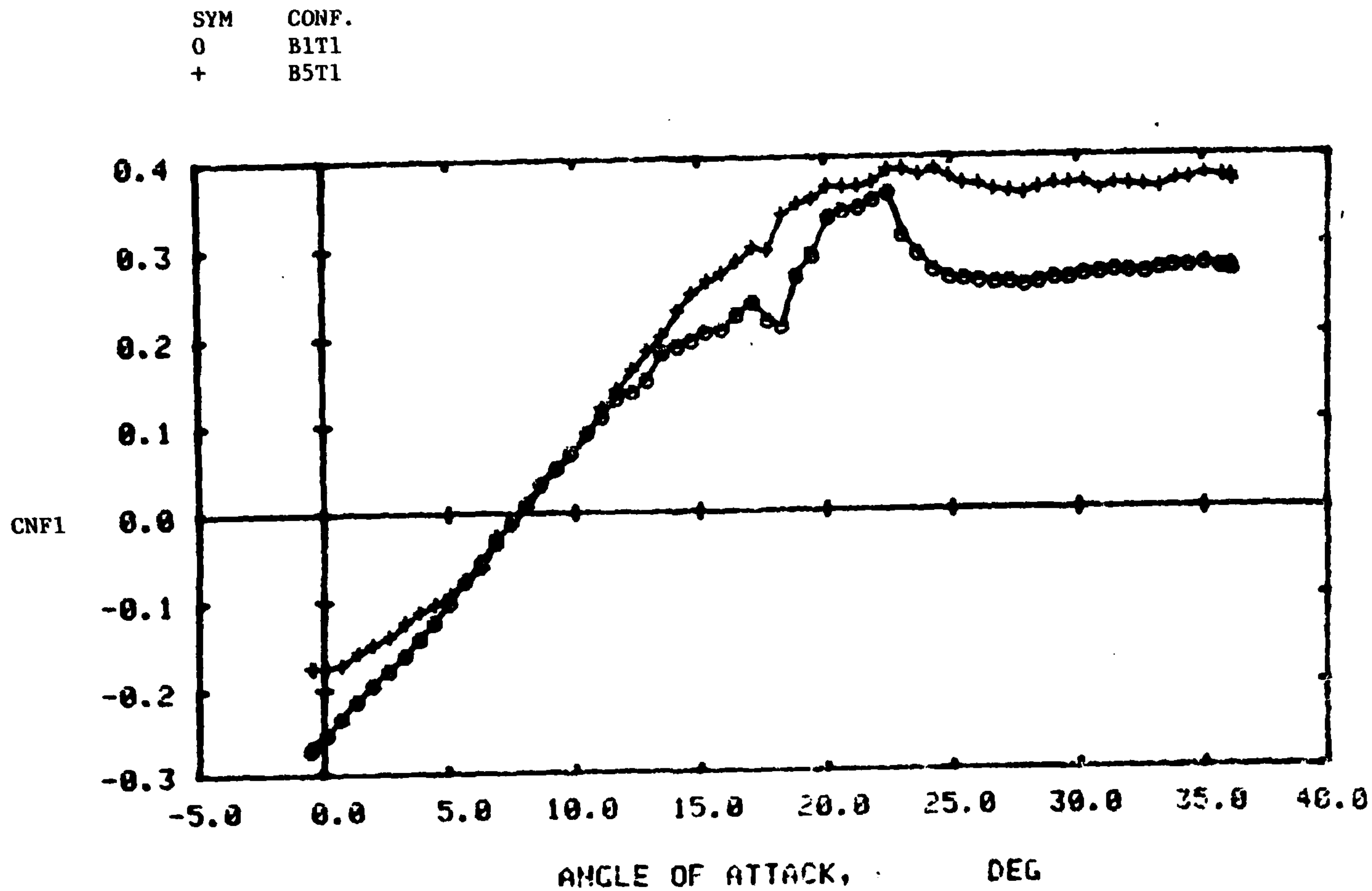
a. Normal Force Coefficient vs Angle of Attack, $\delta_f = 0$.

Figure 6. Effects of Body Slots on Leeward Fin Loads.



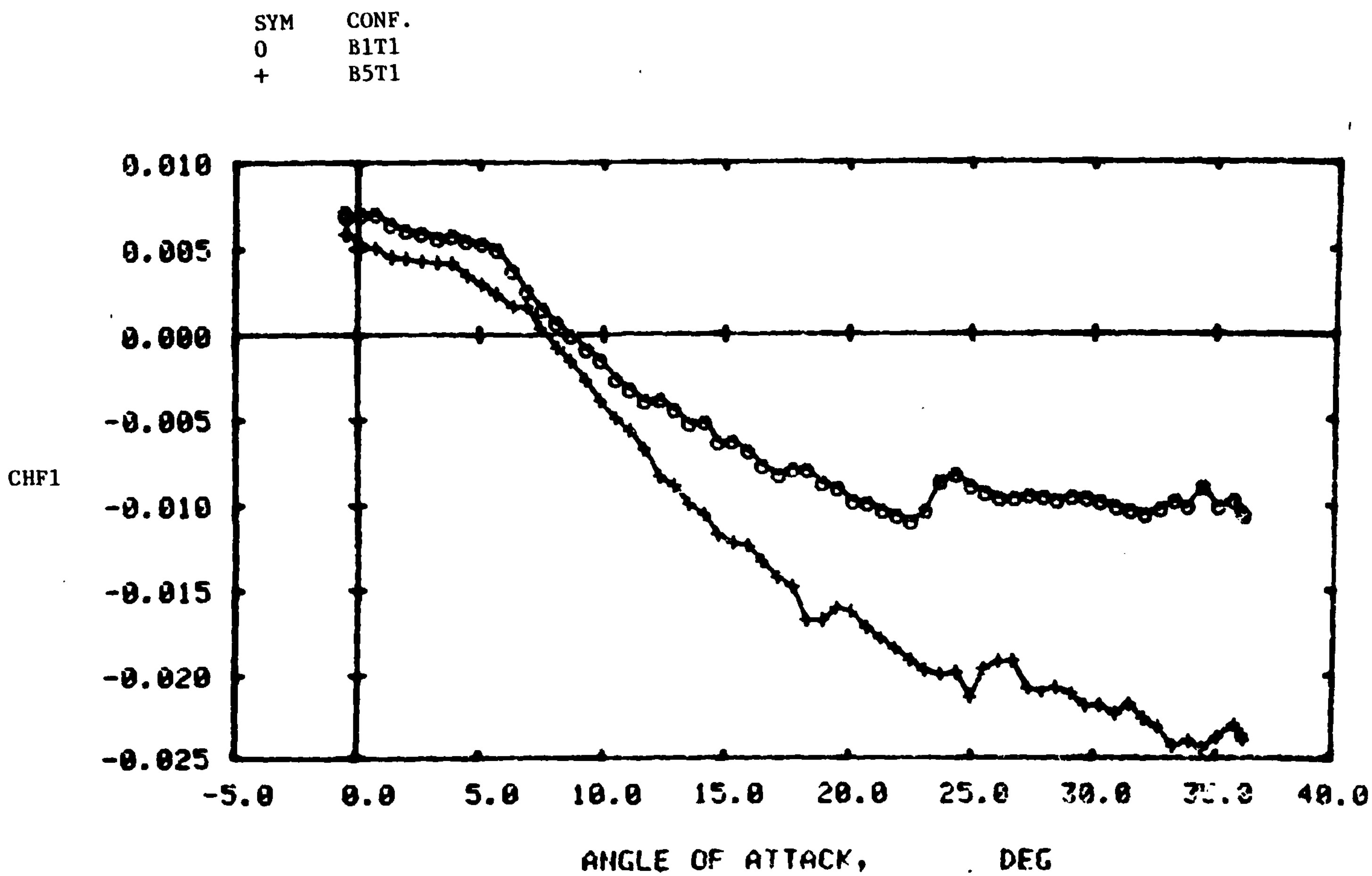
b. Hinge Moment Coefficient vs Angle of Attack, $\delta = 0^{\circ}$.

Figure 6. Effects of Body Slots on Leeward Fin Loads (continued).



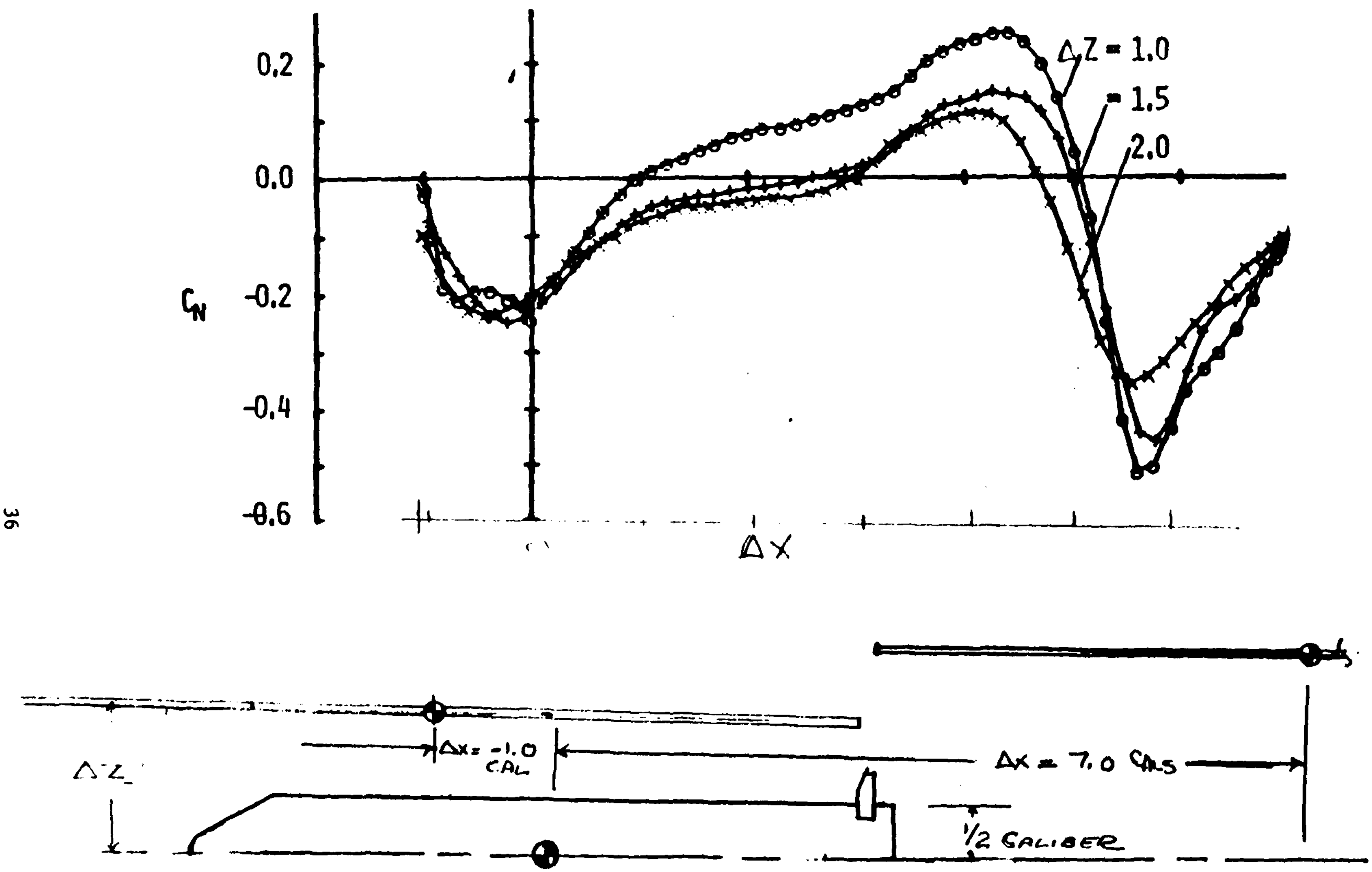
c. Normal Force Coefficient vs Angle of Attack, δf, -7.5.

Figure 6. Effects of Body Slots on Leeward Fin Loads (continued).



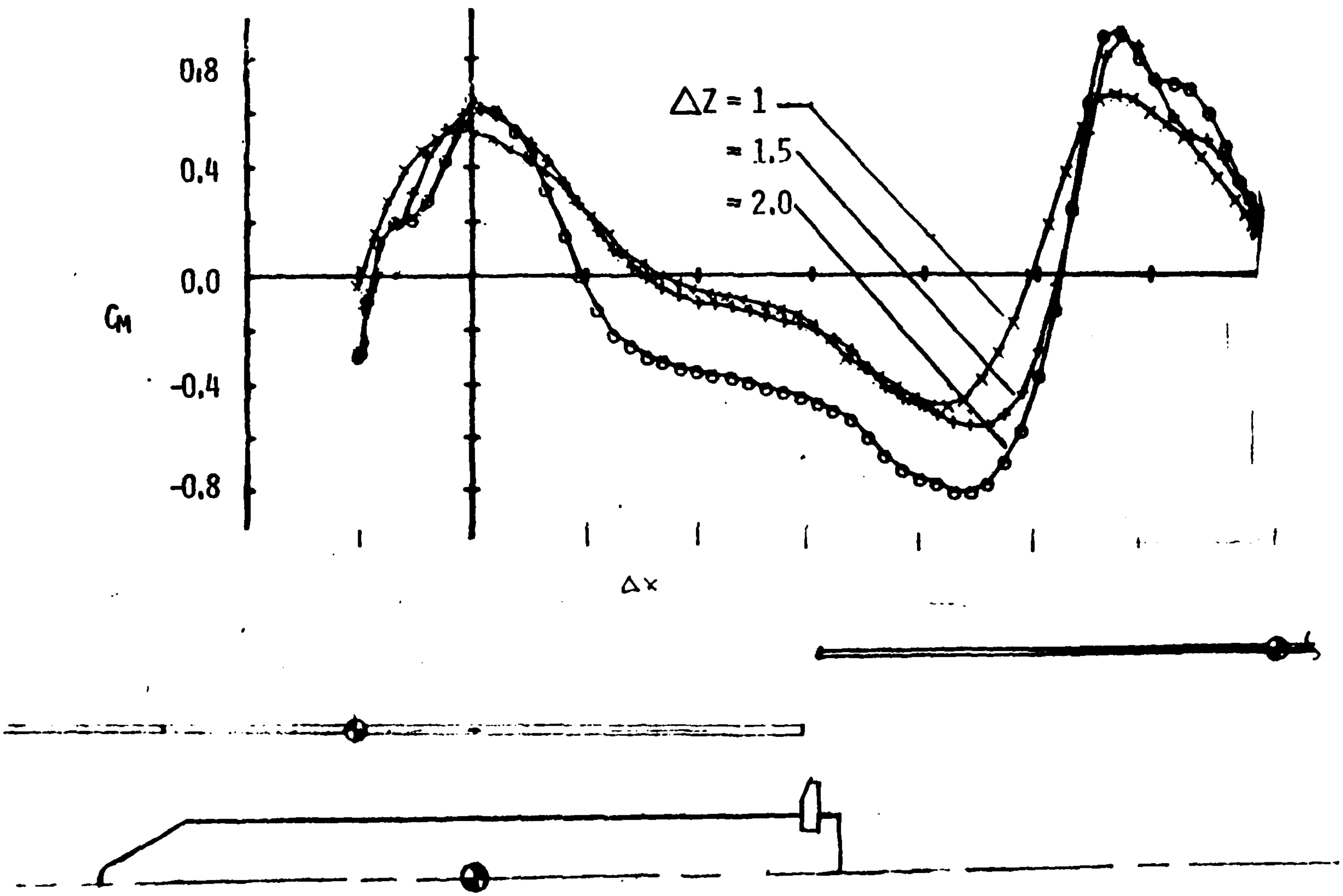
d. Hinge Moment Coefficient vs Angle of Attack, $\delta = -7.5^{\circ}$.

Figure 6. Effects of Body Slots on Leeward Fin Loads (concluded).



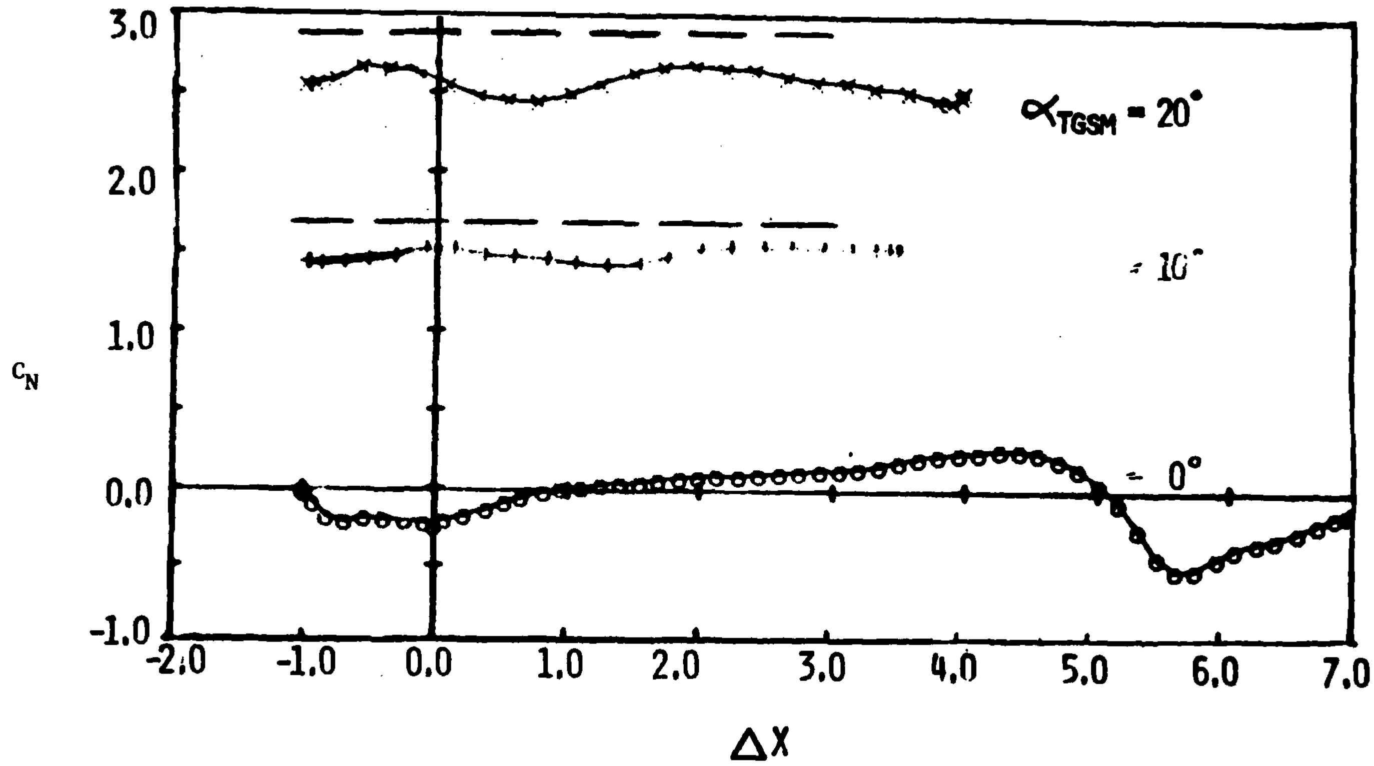
a. Normal Force Coefficient vs Horizontal position.

Figure 7. Effect of panel horizontal and vertical positions on submissile longitudinal stability.



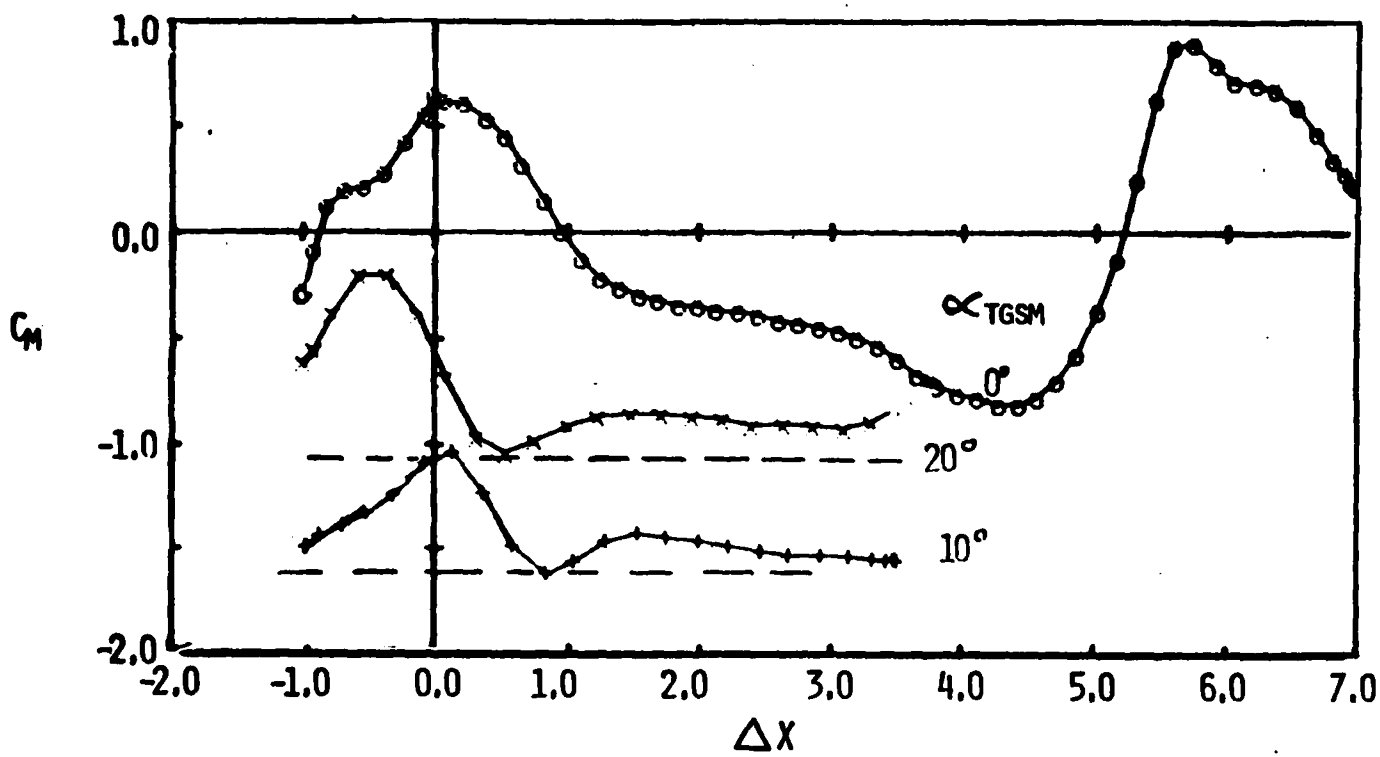
b. Pitching Moment Coefficient vs Horizontal Position.

Figure 7. Effect of panel horizontal and vertical positions on submissile longitudinal stability (continued).



a. Normal Force Coefficient vs Horizontal Position

Figure 8. Effect of panel presence on a submissile at angles of attack.



b. Pitching Moment Coefficient vs Horizontal Position.

Figure 8. Effect of panel presence on a submissile at angles of attack (concluded).

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